νSolve-0.8.2: User Guide

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Chapter 1

Introduction

1.1 VLBI data analysis software

This document describes how to use the geodetic VLBI software νSolve. If a term «geodetic VLBI» is unfamiliar to you, you probably confused νSolve with some other software. It is designed for processing of a single geodetic VLBI session.

νSolve is a replacement of the interactive mode of SOLVE. In this case it works in cooperation the with CALC/SOLVE system. It can also work in standalone mode, in which case it is independent of CALC/SOLVE, and CALC/SOLVE do not need to be installed on your computer. The standalone mode could be useful for VLBI data analysis centers that use their own software and want to generate their own version 4 database.

This is an initial version of the user guide, so many things are not covered and we assume that a user is familiar with CALC/SOLVE. Later, we will extend its content. Additional information on νSolve can be found in [1], [2] and [3].

The guide covers 0.8.2 version of the software. In the older versions, perhaps, not fully implemented all features described here. On the other hand, if you use newer version of νSolve it is worth to find an updated version of the guide too (if it exists).

As it was stated above, νSolve is designed to process a single session of VLBI observations. The main purpose of the software is to prepare a newly available VLBI session for further analysis. In general, this preliminary analysis needs to be done only once for a particular session.

1.2 Requirements

1.2.1 Hardware requirements

There is no special requirements to the hardware. Though, a good monitor with decent resolution will be helpful, νSolve uses GUI to display and let a user to edit VLBI observations.

1.2.2 Software requirements

The software was developed using GNU/Linux operating system, however it does not use any Linux-specific functions, so it should be easily adjusted to work with other POSIX compatible operating systems.

Speaking about Linux, we would suggest to use modern distribution (and make updates on a regular basis), but νSolve can be compiled and run on an ancient systems too.

The software uses several external packages: Qt, netCDF and, optionally, HOPS and libCalc.

The library Qt provides graphical user interface and basic tools. Modern Linux distributions provide Qt, a user have to add development files (C++ header files, utilities, etc.) from the corresponding packages. Consult your system administrator for details. Currently, the version 5 of Qt library, Qt5, is necessary to compile and link the software. The previous version of Qt, Qt4, was used in earlier versions of νSolve distributions but is not supported any more.

Since most of modern distribution ship Qt5 as a default library, no additional keys are required to use the library with νSolve.

The netCDF package provides access to files in netCDF format. This representation of data was chosen to store data in vgosDb format. The netCDF library also is available with modern Linux distributions. As an alternative, a user can install it from the sources available at

ftp://ftp.unidata.ucar.edu/pub/netcdf/

Neither νSolve nor CALC/SOLVE use features that appeared in version 4 or higher of the netCDF library.

The software Haystack Observatory Postprocessing System (HOPS) is required for vgosDbMake utility. You can skip it if you do not want to compile this utility. The distribution package of HOPS is at

ftp://gemini.haystack.mit.edu/pub/hops/

The software is distributed in sources. Version 3.12 or higher of HOPS distribution should be used.

A librarized version of CALC, libCalc, is necessary to compile vgosDbCalc. Previously, libCalc was a part of nuSolve distribution. With the version 0.8.0 of the distribution it was decoupled from nusolve package. The library is available at

`https://sourceforge.net/projects/libcalc/`

1.3 Changes from previous versions

This section was added in 0.5.0 version of the distribution (version 0.5.0 of the νSolve user guide). It covers changes in the software and the user guide.

1.3.1 Changes in version 0.8.2

The sections *4.1 The software preferences* and *6.2 Session Editor* were updated to reflect the latest changes in software configuration and session editor.

A user can specify extensions for master file names and order to search, subsection *4.1.1 Specifying directories, external files* was updated to reflect the changes.

If a user has provided session name to read, nuSolve can filter out wrapper files that were produced by other analysis centers even if the wrapper files have higher version number, see subsection *4.1.2 Software options* for the details.

Cable calibration corrections origin is added to the list of stations, a user can cahnge the origin of cable calibraiton corrections (if data are available), see subsection 6.2.4 Tab «Stations (List)».

1.3.2 Changes in version 0.8.1

A couple of bugs in the software were fixed, there are no visble changes to the User Guide.

1.3.3 Changes in version 0.8.0

Due to forthcoming licensing requirements the sources of CALC and nuSolve are decoupled. To compile vgosDbCalc a user have to install libCalc first. The sources of vgosDbCalc now does not contain CALC codes. In the case if libCalc is missing, the utility will not be configured and compiled. Chapter *2 Installation* was modified to reflect this change.

All external source codes (about a dozen of functions, external and derived from SOLVE sources) were replaced with the the independent source code.

Starting with this version, nuSolve supports version 2 of masterfile format and new database naming convention.

1.3.4 Changes in version 0.7.6

The release contains few bugfixes: update of *configure* script and sources to work with GCC 12.1 (thanks to Leonid Petrov); proper designation of CDMS cable calibration type when the data were extracted from FS log files (thanks to Arthur Niell); changing of a name of vgosDb variable that accumulates cable calibration of different types (thanks to Haystack VLBI group).

1.3.5 Changes in version 0.7.5

This version introduces multi-thread matrix triangulation. For multi-core CPU such parallel computations will decrease time of processing a session. See Chapter *3 Invoking νSolve* for the details.

GUI is added to plot all available cable calibration corrections. Also, a user can control what type of the correction should be used in a solution. It can be set up for a whole session or on a per station basis. The subsection *6.2.4 Station Attributes Editor* discusses how the type of cable calibration corrections can be changed using GUI mode of the software. The script mode support of this feature is covered in subsections *8.3 Solution configuration in scripts* and subsections *8.6.2 The object «Station»*.

A station attribute "bad meteo parameters" is added. If it is set, then a "standard" values of temperature, pressure, and relative humidity are using in a solution. This option is discussed in subsection *6.2.4 Tab «Stations (List)»* for GUI mode and in subsections *8.6.2 The object «Station»* for script mode.

Sources of the plotter subsystem has been modified so the software can be compiled with Qt5 version 5.12 or older.

The spoolfile file output was updated: a name of reported database now does not depend on a primary band (will work for databases with names like 22MAY16MH).

1.3.6 Changes in version 0.7.4

Various bugs have been fixed.

The command line arguments parser has switched to ARGP from GNU C Library.

The plotting subsystem now can save plots in raster formats (JPG, PNG, PPM). The subsection *4.1.1 Specifying directories, external files*, *4.1.2 Software options*, *4.1.3 User's identities* and *4.1.4 Configuration of logging subsystem* were refreshed.

For testing purposes the following options were added. The fly-by mapping function can be calculated as MTT or NMF mapping function. The software can read external EOP files (implemented formats: USNO and IERS EOP). For details see *4.2.3 Applying different models and using external a priori information*.

The Chapter *8 Scripting support* was updated to refresh changes in the script mode.

1.3.7 Changes in version 0.7.3

The configure script has been reworked. A mandatory option `--with-calc-datadir=` is added, see details in Chapter *2 Installation*.

The script that converts vgosDb to and from vgosDa format, vgosDxConvertor, has been reworked, Section *9.1 Converting data format of a VLBI session* was refreshed.

1.3.8 Changes in version 0.7.2

A new utility, log2ant, is added to the distribution. It extracts various sensors readings from a station log file and stores them in ANTCAL format. See log2ant User Guide for details.

The utility vgosDbProcLogs extracts and stores in vgosDb format tsys data (if available).

The software now requires Qt5, the realization of regular expressions in Qt4 is too slow.

An option to generate a list of commands to refringe selected by a user observations is implemented. It should be useful to deal with subambiguities.

The General Configure Editor was modified to allow a user to control using of observations with fourfit error codes «G» and «H».

In Preferences, Logger Options, an option to print full date in the log output is added.

1.3.9 Changes in version 0.7.1

The distribution has switched to Qt5 as a default version of Qt library. The old version, Qt4, is still supported. It simplifies software compilation. See details in Chapter *2 Installation*.

Format of the file «nuSolve_unused_observations_??» was slightly changed, two columns with fourfit error codes are added.

In a script mode a user can add comments in a script, these comments will be printed in corresponding spool file (in a case if it is created), see *addUserComment2Report()* in Section *8.5 Manipulations of input/output operations for a VLBI session*.

In addition to CALC a priori files, starting with 0.7.1 distribution version the SOLVE external a priori files are shipped to. The files are:

ECCDAT.ecc	a file with eccentricities of stations
glo.sit	external a priori of station positions
glo.vel	external a priori of station velocities
glo.axis	external a priori of station axis offsets
glo.src	external a priori of source coordinates
glo.ssm	parameters of the multipoint source source structure model
last.erp	a file with Earth rotation parameters
glo_baseline.wgt	a file with baseline weights
gsfc_dao_9095.mgr	a file with average atmospheric gradients
jmg96.hf	a model of diurnal/semidiurnal ERP variations

The files are used by νSolve, they have to be placed in the proper directory and the software should be configured correspondingly, see *4.2.3 Applying different models and using external a priori information*.

1.3.10 Changes in version 0.7.0

The version contains two significant new features: a point like source structure model has been added (GUI and script modes) and dealing with vgosDa files was implemented. Various bugs have been fixed.

The section *6.2.5 Tab «Sources (List)»* has been extended with using the source structure model and source attribute editor.

A per source view of data was added, see the subsection *6.2.3 Tab «Bands»*.

The subsections *4.2.1 General options*, *4.2.2 Run time options* and *4.2.3 Applying different models and using external a priori information* were refreshed to reflect updates.

A section *7.2 Using a source structure model* has been added.

1.3.11 Changes in version 0.6.4

This update contains minor bug fixes.

An option to import a default wrapper file was added, see the subsection *6.1 Reading a session*.

1.3.12 Changes in version 0.6.3

This update contains bug fixes.

A number of scans was added to the list of sources, see the subsection *6.2.5 Tab «Sources (List)»*.

1.3.13 Changes in version 0.6.2

A sign that was applied to extracted from log files cable calibration measurements for each station is added to the list of stations, see the subsection *6.2.4 Tab «Stations (List)»*.

In this version νSolve is capable to exclude some baselines from weight correction procedure. A user can manually select such baselines, see the subsection *6.2.6 Baseline Attributes Editor*.

The subsection *4.2.2 Run time options* has been updated: a user can add initial and minimal values for additional weights for delays and rates.

Two short-cut were added to the Session Edit window: *Ctrl+h* (makes output of estimated stochastic parameters into ASCII files) and *Ctrl+z* (exports total zenith delays into ASCII files). See the Section *6.2 Session Editor* for details. These operations are available in a script mode too, see the Section *8.5 Manipulations of input/output operations for a VLBI session*.

1.3.14 Changes in version 0.6.1

The chapter *3 Invoking νSolve* has been modified with description of using system-wide settings.

The section *8.2 Software set up in scripts* is added to discuss software set up alternating in a script mode.

The table *6.1 Shortcuts of Session Editor window* of the section *6.2 Session Editor* has been extended with *Ctrl+a* shortcut action (export aposteriori source coordinates and station positions in the format of a priori files).

The figure *4.8 Configuration: use of contributions and external a priori information* of the section *4.2.3 Applying different models and using external a priori information* has been updated to show added *GPS ionosphere correction* contribution.

The URL of software distribution has been updated in the chapter *10 Concluding remark*.

1.3.15 Changes in version 0.6.0

The subsection *6.2.5 Tab «Sources (List)»* was refreshed for modified content of source view list in a session mode.

A description how to highlight all observations with a particular source was added to the subsection *6.2.3 Tab «Bands»*. Also, description of an observation info window was added to the subsection.

The subsection *6.2.8 Not used observation window* is added, it describes the *Not used observation* window.

The chapter *3 Invoking νSolve* has been updated to reflect the changes in command line arguments – the option «-t» was added to run in a script execution mode.

A chapter *8 Scripting support* was added. It describes how to use scripting engine in νSolve.

1.3.16 Changes in version 0.5.0

The subsections *7.1.3 Resolving ambiguities* and *7.1.4 Processing a clock break* have been modified to reflect the latest modifications of the software.

In this version the graphical user interface of lists of stations, sources and baselines has been improved. The subsections *6.2.4 Tab «Stations (List)»*, *6.2.5 Tab «Sources (List)»* and *6.2.6 Tab «Baselines (List)»* were updated to reflect changes in the GUI.

The software can display three subsets of observations: all, usable and good. This feature is discussed in *6.2.3 Tab «Bands»*.

The ability to read only one database or databases that have alternative names was added to νSolve. This feature is covered in the section *6.1 Reading a session*.

Description how to apply a contribution from the tropospheric refraction is added to the subsection *4.2.3 Applying different models and using external a priori information*.

νSolve is capable to process phase delays and delay rates. Notion about it is added in the subsection *4.2.1 General options*, as well as peculiarities of the automatic switching of observable types are described there. Also, description of the «Novice User» mode is updated in the subsection.

The subsection *4.2.2 Run time options* has been updated: an option *Downweight delays* was added.

The software is able to read an alternative version of master files. The use of the local master files is described in the section *4.1.1 Setting paths to data*.

The sections *1.2 Requirements* and *1.3 Changes from previous versions* were added to the chapter *1 Introductions*.

Chapter 2

Installation

The source codes of νSolve is distributed as a part of CALC/SOLVE software. Also, the latest stable version of the software is at `https://sourceforge.net/projects/nusolve/` with a name like `nusolve-1.2.3.tar.gz`. Since the software is still in an active development phase, we recommend you use the latest version.

The distribution package `nusolve-0.7.2.tar.gz` and later versions, contains five utilities: νSolve, vgosDbMake, vgosDbCalc, vgosDbProcLogs and log2ant. The utility vgosDbMake extracts some data from fringe files and creates a vgosDb set of files for a VLBI session. vgosDbCalc calculates theoretical values and partials, stores these information in the vgosDb format. The utility vgosDbProcLogs extracts additional information (cable calibration and meteorological parameters) from stations log files and adds it to a vgosDb set of files. The utility log2ant extracts various sensors readings from station log files and stores them in ASCII files in ANTCAL or ANTAB format. By default, only νSolve, vgosDbCalc, vgosDbProcLogs and log2ant will be compiled and installed. To build the utility vgosDbMake it is necessary to have HOPS (Haystack Observatory Post-processing System) software installed.

Each of utilities as well as the core library has its own versions number. The version numbers and the distribution version number not necessary be the same.

Before installing the software you should check for two external packages which νSolve depends on. The Qt library provides the graphical user interface. The netCDF library deals with I/O operations in Common Data Form format. Practically, all modern Linux distributions contain both libraries. There is a good chance that Qt library is already installed on your computer (check your package manager or ask a system administrator). If, for some reason, you cannot or do not want to install these packages system-wide, you can download the sources and and install them in your home directory. In this case (also, if the system installation put the library(ies) in non-standard places) you will need to provide paths to include files and libraries to the configure script.

Optionally, if you want to compile vgosDbMake utility, you need to install Haystack Observatory Postprocessing System, HOPS. The HOPS software should be installed manually, it is available from the site of Haystack Observatory

`https://www.haystack.mit.edu/haystack-observatory-postprocessing-system-hops`

The first step in installing νSolve and accompanying utilities is to extract the files in a temporary directory and cd to it. Run a configure script in the root directory of the package:

```
> ./configure <options>
```

Where a list of options of the configure script can be retrieved issuing

```
> ./configure --help
```

Several options are worth mentioning here. The place where to install the software:

```
--prefix=[PREFIX]
```

By default, it is `/usr/local`. If you do not have permissions to write there (which is a sign of a properly configured system), a user can install the software into his/her home or somewhere else. In this case, it is useful to add `PREFIX/bin` to your `PATH` environment variable. Also, you may need to add `PREFIX/lib` to your `LD_LIBRARY_PATH` variable.

Starting version 0.7.1 of the distribution, the package is tailored to work with Qt library of version 5 that is shipped by default by most of Linux distributions. The configure script supposed to find all necessary files without any special commands. If you previously installed Qt4 from sources, remove path to its executable binaries from your PATH environment variable and verify if it works: run a command

```
qmake -version
```

and check the output, the version of Qt library should be 5. In this case the configure script have to find all necessary files (if they are installed, of course) without additional options.

The configure script searches for Qt's files using output of `qmake` utility, make sure it is installed and is in your `$PATH`.

The software uses the following modules of Qt: QtCore, QtGui, QtWidgets and QtScript. Make sure that these packages and their development counterparts (*-dev packages) are installed on your computer.

Starting with version 0.7.2, the Qt library of version 4 is not supported.

In the case when Qt library is installed manually in a non-standard place (i.e., in a user home direcory), a user can provide option `--with-qt-dir=DIR` to specify the place where Qt5 is installed. With this option configure script expects that parts of Qt library are installed in standard places: the header files are in `DIR/include`, the libraries are in `DIR/lib` and the executables are in `DIR/bin`. If the these parts of Qt library are in non-standard places, then a user should use the following three options: `--with-qt-include=DIR`, `--with-qt-lib=DIR` and `--with-qt-bin=DIR`. Note, in this case all three options have to be explicitly provided.

To point out on non-standard places of netCDF files, use the following options:

```
--with-netcdf-include =[PATH_TO_NETCDF includes]
--with-netcdf-lib     =[PATH_TO_NETCDF libraries]
```

to specify where the include file and the libraries are.

By default, the utility vgosDbMake is not compiled. To trigger on the compilation of vgosDbMake, the configure script expects one of the following options:

```
--with-hops-dir=[PATH_TO_HOPS]
```

or

```
--with-hops-include=[PATH_TO_HOPS include files]
--with-hops-lib=[PATH_TO_HOPS libraries]
--with-hops-share=[PATH_TO_HOPS shared data]
```

Even if your HOPS library was configured with `--prefix=/usr/local` and all files are in standard places, you need to provide the option `--with-hops-dir=/usr/local` to turn on compiling vgosDbMake utility.

Starting with version 0.8.0 of νSolve distribution, sources of CALC are distributed separately from nuSolve. A user should download and install libCalc first before compiling vgosDbCalc. The sources of libCalc are available at

```
https://sourceforge.net/projects/libcalc/
```

The data files that are necessary to run vgosDbCalc are moved to libCalc package and no more a part of νSolve distribution.

To specify where libCalc was installed provide the following argument to the configure script: options:

```
--with-calc-lib=[PATH_TO_LIB_CALC_PREFIX]
```

here PATH_TO_LIB_CALC_PREFIX is a name of a directory that was used during configuring libCalc. For example, if libCalc was configured as (assuming that it will be installed in /home/slb/Software directory):

```
./configure --prefix=/home/slb/Software --with-calc-datadir=/sgpvlbi/apriori/calc
```

then run the configure script from nusolve package as

```
./configure --with-calc-lib=/home/slb/Software [OTHER_OPTIONS]
```

In the case if libCalc is not installed or not found by the configure script, sources of vgosDbCalc will not be configured and compiled. So, the users that are not interesting in vgosDbCalc should not worry about presence of libCalc.

In the file `INSTALL.local` in the root of the distribution tree one can find details about specifying configure's options to assemble the software with Qt and netCDF libraries[1].

If the `configure` script finished without errors, type the following commands:

```
> make
> make check
> make install
```

and the software will be installed in the `PREFIX` directory. The command `make check` is optional, it is a placeholder for checking suite that will be developed later. Please ignore any errors reported during `make check`.

In addition to the executable files, the software puts files with a priori information into `($datadir)/nuSolve`, where `$datadir` is `PREFIX/share` (if it is not overwritten by a user). These files are a priori files for CALC (see vgosDbCalc User Guide) and external a priori files for nuSolve, see subsection *4.2.3 Applying different models and using external a priori information*. User should put these files in the directory that is specified in the software preferences, subsection *4.1.1 Specifying directories, external files*. Both groups of files, a priori for SOLVE and external a priori files for nuSolve, needs to be updated with time. Use the URL

https://cddis.nasa.gov/archive/vlbi/gsfc/ancillary/solve_apriori/

to maintain SOLVE a priori files. The external a priori file for nuSolve a user can modify by him/herself.

[1] Do we need to duplicate that information here?

Chapter 3

Invoking νSolve

To invoke νSolve just type (specifying if necessary the full path to the executable):

```
> nuSolve
```

νSolve also accepts command line arguments. The arguments consist of two groups of options and a name of a database to open by the software. The first group of options is related to Qt library and controls how the application will appear and behave. See Qt documentation about details, (e.g., https://doc.qt.io/qt-5.14/qguiapplication.html). The another group of options is used by νSolve itself. To get the list of these arguments, type

```
> nuSolve -help
```

Here are command line arguments that are available at the time of writing:

	Configuration control:
`-a, --alt=STRING`	Use an alternative configuration STRING.
`-d, --default-setup`	Use default setup (WARNING: existing configuration will be overwritten).
	Script mode:
`-t, --script=STRING`	Execute a script STRING.
	Automatic processing (GUI mode):
`-m, --force-automatic`	Force executing of automatic processing.
`-n, --no-automatic`	Do not run automatic processing even if a session is eligible for it.
	Input control:
`-c, --catalog`	Force run in the catalog aware mode (opposite to '-s').
`-f, --format=STRING`	Set the data storage format of the provided session to STRING (either "dbh" or "vgos").
`-l, --read-all`	Read all databases, even that that lack of essential information.
`-s, --standalone`	Force run in the standalone mode (opposite to '-c').
	Invocation of startup wizard:
`-w, --wizard`	Force call of the startup wizard.
`-W, --sys-wide-wizard`	Run startup wizard for the system-wide settings.

Execution control:

`-i, --no-interruptions`	Do not catch interruptions.

Operation modes:

`-?, --help`	Give this help list.
`--usage`	Give a short usage message.
`-V, --version`	Print program version.

Most of these are used either to override the current software configuration or for the debug purposes.

If a user invokes *-t* option, νSolve will run in execution script mode. In this case all other arguments will pass to a script. It is up to a user how to deal with arguments in a script, however, the arguments should not start with «–» character, otherwise they will interfere with νSolve's argument parsing. Example of invoking a script:

```
> nuSolve -c -t export2ngs.js 18JAN03XU
```

Here a script «export2ngs.js» exports a VLBI session into an ASCII file in NGS format. The name of the session, 18JAN03XU, is provided as a command line argument. The option *-c* is added to override the default mode of use local files and to run νSolve in the catalog aware mode. The file export2ngs.js is available in the distribution package in a directory *scripts*.

Without *-t* option, an optional command line argument is considered as a name of a session that should be processed in a non-interactive mode. Invoking the software with a session name turns νSolve into a «command-line mode»: no user graphics interface will be issued (and no X-server connections required), the software processes a session according to the configuration of post import actions (see 4.2.4). In the case of successful analysis the new version of the database will be saved as well as a separated log file (if it is not disabled by software preferences). Executing the software in this mode is designed to process INT type sessions only. Invoking it for 24-hr sessions will produce unpredictable results.

The data format of an input session is controlled by *-f* option. If the option is missed, the **vgosDb** format of VLBI observations is assuming.

The session name can be either a file name of a one of the bands (in the standalone mode) or a name of database with or without version (in the catalog aware mode). For example, if νSolve is configured to work in the standalone mode to process a new INT session I can invoke it as

```
> nuSolve -f dbh /home/slb/500/databases/17APR09XK_V003
```

assuming that two database files, `17APR09XK_V003` and `17APR09SK_V002` are in the directory `/home/slb/500/databases`. With the same software set up I can process the same session using catalog I/O typing

```
> nuSolve -c -f dbh 17APR09XK_V003
```

or

```
> nuSolve -c -f dbh 17APR09XK
```

The last invocation will pick up the database with the latest version. If you specify a version number that is not the latest one, the software will refuse to save results.

It is convenient for routine analysis of VLBI sessions to set up separate configurations for different types of VLBI networks. For example, for test or debug purposes I invoke the software just typing

```
> nuSolve
```

To make a routine analysis of newly available IVS-R4 session I call it

```
> nuSolve -a R4
```

where `R4` is a name of a configuration set that will be used for the analysis. And to process intensive sessions I call it as

```
> nuSolve -a INT
```

When `nuSolve` is invoked the first time or new alternative configuration name has been provided, it calls a setup wizard. The wizard is a small application that asks a user few questions about the configuration.

On a system with several users it is useful to set up common software settings, like path to observations, data files, and so on. To set up such settings, invoke it with `-W` option. Obviously, you have to have write access to the directory with system-wide settings. By default, the system-wide settings directory is derived from *${prefix}* variable of the `configure` script and is set to *${prefix}/etc/xdg*. It can be overwritten using *–sysconfdir* option of the `configure` script.

The system-wide settings take an effect if user settings do not exist (e.g., first run of the software), changing the system-wide settings will not affect existing user's settings.

Combination of the option `-W` with the option `-a AltCfg` discards using the system-wide settings, the setup wizard will use the alternative setup instead.

Starting with version 0.7.5 of the distribution, νSolve can perform parallel computations of matrix triangularization (one of the most time consuming part of solving normal equations). The parallelization is implemented with Linux threads. An environment variable NUSOLVE_NUM_THREADS is controlling the parallel computation. If the variable is set to a natural number, νSolve will use this number as a number of threads. If the variable is not set, νSolve calls `sysconf(_SC_NPROCESSORS_ONLN)` to figure out the number of processors and uses the obtained value as a number of threads.

For testing purposes, if NUSOLVE_NUM_THREADS is set to zero, νSolve will use sources that are not parallelized (i.e., from the previous versions), the number of thread 1 or greater cause νSolve to use new source tree that performs parallelization.

For example, if you are running νSolve and suspect something wrong due to parallel computations, you can turn off parallelization using your POSIX compatible shell:

```
> NUSOLVE_NUM_THREADS=0 nuSolve [options]
```

In this case the software will use the old piece of the code.

The goal of using the parallel computations is to reduce the time of session processing. The actual reduction depends on a number of CPU cores of your computer. For example, a processor i7-10750H has six cores, so using the parallel computations can reduce time of execution in approximately six times.

Chapter 4

Configuring the software

The software stores its preferences using Qt's QSettings class. There are two types of settings. One reflects on how the software will behave in general, specifies paths and file names, keeps user name, etc. This part is called "preferences" in this guide. Another part, which we call "configuration", determines: 1) which models and how they will be applied in the data processing, 2) lists a set of estimated parameters, 3) etc, etc. In the next section we will overview the preferences. The section 4.2 will deal with the configurations.

4.1 The software preferences

To open a dialog window with preferences, select menu *Edit–>Preferences* or press *Ctrl+r* keys.

4.1.1 Specifying directories, external files

The first tab, *Directories*, displays file names and paths to various directories. An illustration of the tab is shown on Figure 4.1.

The νSolve's home directory is defined in the field *Home (non-absolute paths count from it)*. The software can read and write many files in different formats. To keep all output in one place we made this home directory. All other directories for input and output are relative to the home directory unless they star with the slash «/» symbol, in which case they are assumed to be absolute paths. There is one exception from this rule – the directory to CALC/SOLVE binaries (the next field). Usually, CALC/SOLVE software is installed in one common place on the computer and it is assumed that all users have access to the software and its files. So, there is no sense to expect its binaries in νSolve's home directory. If a user wants to specify a directory that is outside from νSolve's home, it can be done in the absolute form.

The field *Executables of Catalog <–> nuSolve Interface* specifies a path to the couple of executables, `catnu_find_db` and `catnu_update_cat`, that are necessary to communicate with CALC/SOLVE's catalog. If you do not have CALC/SOLVE on your computer, you can ignore this field.

The path to files in the database handler format (DBH) is given in the field *Observations (DBH) files*. The field *Observations (vgosDb) files* displays the path to files with observations in the new VLBI data format, vgosDb. Files in vgosDa (also known as AGV) format are in a directory *Observations (vgosDa) files*.

νSolve can work with files in DBH format in two modes. One mode, standalone, assumes that CALC/SOLVE software is not installed, or the results of data processing will not be used in CALC/SOLVE. In this case it opens user specified files and saves results in the same directory in a file with a similar name, but with the increased version number. In the second mode, interaction with CALC/SOLVE catalog subsystem, it calls the executable `catnu_find_db` of CALC/SOLVE to inquire about a user-specified database name. After processing the database is stored with the increased version number, and the CALC/SOLVE catalog is informed about the new file by calling `catnu_update_cat` executable.

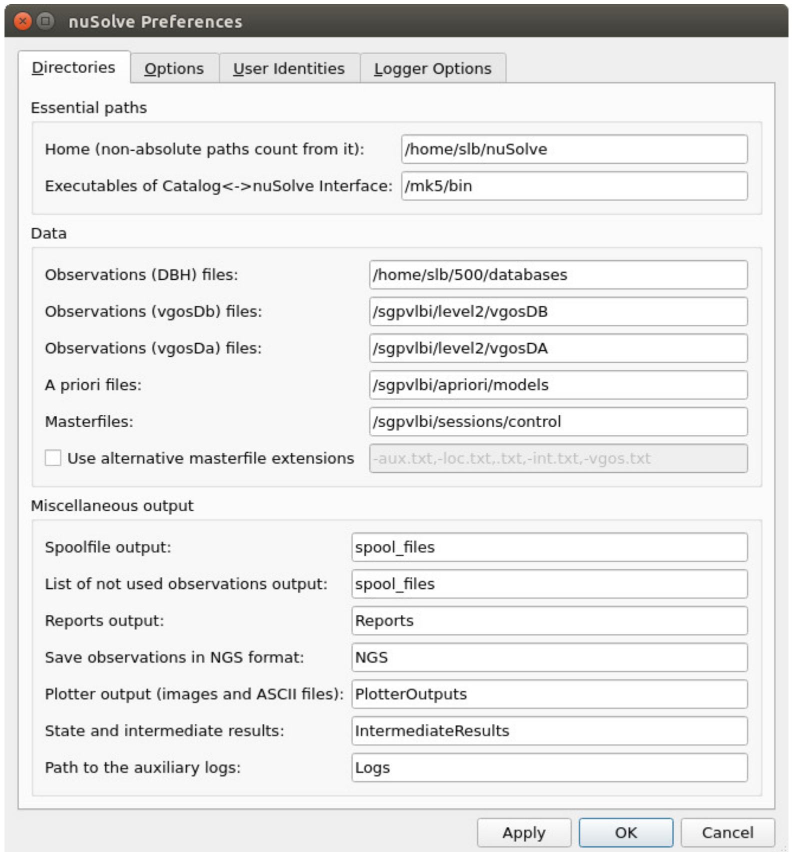


Figure 4.1: GUI to set up paths and file names.

The field *A Priori files* specifies where to look for files with alternate *a priori* information about site positions, source coordinates, antenna axis offsets, etc. All this files are in CALC/SOLVE format. You can ignore this if CALC/SOLVE is not installed.

The directory which contains the masterfiles is pointed to by *Masterfiles* field. Masterfiles are contain information about VLBI session and are necessary to produce correct output. There is one masterfile for each year. You can download the masterfiles from

`https://cddis.nasa.gov/archive/vlbi/ivscontrol/`

The masterfiles are updated if the VLBI master schedule changes and you should periodical get the latest versions. In addition to the standard master files, a user can use its own "local" master file. The format of the local master file should be the same as the standard one, its name have to be in the form "masterYY-loc.txt", where "YY" – two digits of the year. This feature is designed for testing purposes or processing non-standard VLBI sessions. The software first checks for the local master files, if it found a record there it stops the search, so records in the canonical master files can be overwritten using the local master file.

Starting with version 0.8.2 of the distribution, an option to expilictly set names for master files is added. If a user sets the check box *Use alternative masterfile extensions* to "on", then nuSolve will compose the masterfile names using a provided list of extensions. The list is a set of strings separated by comma (","), colon (":") or semicolon (";") char. The software adds the extension from the list to the basic name, "masterYY" or "masterYYYY", and reads such a file. The order of files lookup is corresponding to the order of masterfile extensions in the list. The default list of masterfile extensions is "-loc.txt,.txt,-int.txt,-vgos.txt".

The directory in the field *Spoolfile output* is used to store a report about results of data processing in CALC/SOLVE spoolfile format. The file name is «SPLF??» where the last two chars are user's initials (see the next section). This file is used in routine data processing by other parts of CALC/SOLVE system.

The field *List of not used observations output* specifies a place where νSolve will put a file with a list of observations that are not in a solution. The list is created at the same time when the report in a spoolfile format is written. The file name has a form of «nuSolve_unused_observations_??» where the last two chars are user's initials.

If a user desires, a copy of the spoolfile may also be be saved in the directory pointed by the field *Reports output*. (See *Copy spoolfile reports into "Report" directory* on the next tab.) In this case a file name will be altered from the general «SPLF??» to the form of «[database name].SFF», e.g., *13SEP12XE.SFF*.

The software νSolve can export a VLBI session in the ASCII NGS format. The field *Save observations in NGS format* points to the directory to put the this output.

The plotting subsystem can save data as ASCII files or graphics (in PS or PDF format). All output will go into a directory specified in the *Plotter output (PS, PDF or ASCII files)* field.

The field *State and intermediate results* specifies a path to files with saved intermediate results, editings and sets of parameters.

When software is invoked in the command line mode, it, in addition to the standard log file, can save logging information into a separate for each session file. The field *Path to the auxiliary logs* points to the directory with such logs.

4.1.2 Software options

The tab *Options* contains the following selections (Fig. 4.2).

If the checkbox *Database operations are going through the catalog* is «on», νSolve will use the CALC/SOLVE catalog subsystem.

The option *Saving a database with alternate session code (for tests purposes)* is used for tests. If it is «on» the name of the database will be altered so it will be possible to have different solutions for comparisons.

If the option *Copy spoolfile reports into "Report" directory* is selected, νSolve will make a copy of the report in spoolfile format as a separate file (see above).

The checkbox *Warn me when closing Session Editor Window* switch «on/off» determines if νSolve will issue a warning when a user closes the Session Editor Window. This is because a click on *Close* button of the window would destroy your work if you are not done with your analysis.

For some displays with small resolution the Session Editor window will not fit on the screen. In this case turn the *Make horizontal layout in the Session Editor* checkbox «on». It will put a series of buttons on the right instead of bottom of the window. The software is still in developmental mode and in future releases we will redesign the window to overcome this problem.

In general, when a user specifies a file name with a database, νSolve automatically looks for files of the session with other bands and reads them too. E.g., if a user asks to open *13SEP12XE* file, it will pick up *13SEP12SE* too (if it exists). To override this behavior uncheck the *Autoload all bands* checkbox. If this box is not checked only one file will be opened.

Running in the command line mode the software will save per session log files if the checkbox *Save a log file for each session (command line mode only)* is set to «on», otherwise the logging information will be lost.

If the checkbox *After saving execute a command* is set to «on», νSolve will run a command that is specified in the next field every time when it saves a session in a new database or vgosDb files. The command can be either a binary executable or a script, it have to be in the user's PATH or a full path have to be provided. Five arguments are passed to the command: a database name, an official session code and name (the both fields are from a masterfile), network ID and user's initials. For example, assume I have a script *testExternalCommand* in a place that is listed in my *$PATH* environmental variable and the script consists of a simple instruction

```
#!/bin/bash
```

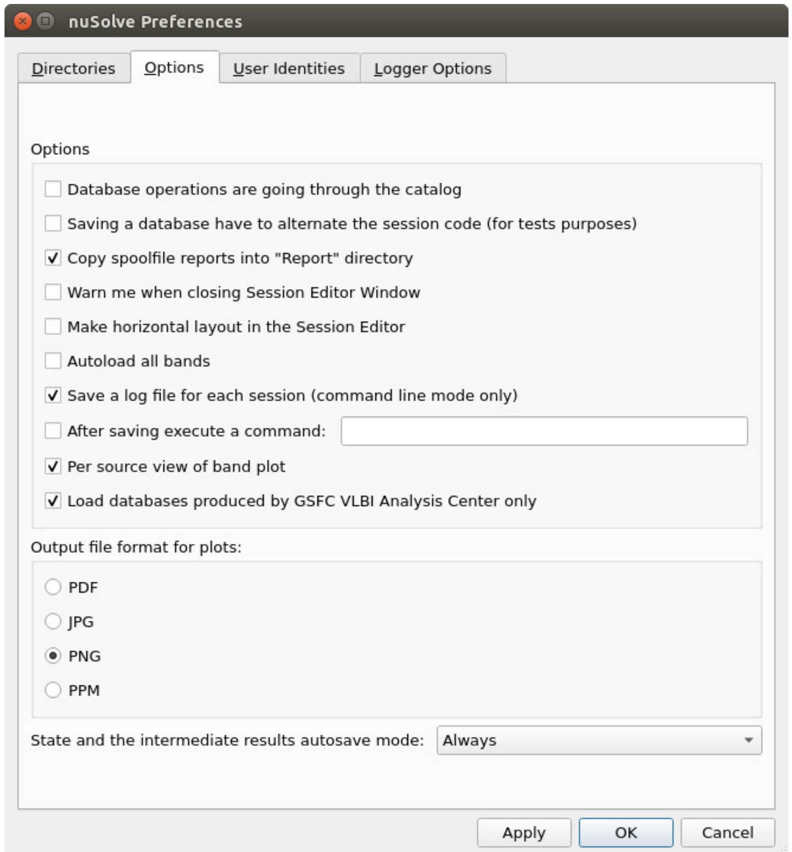


Figure 4.2: GUI to set up νSolve's options.

```
echo $1 $2 $3 $4 $5
```

Then, when I have processed a session *$17FEB23XE* and pressed *Save* button the following string will also be sent to the standard output:

```
$17FEB23XE R4780 IVS-R4780 IVS-R4 SB
```

The checkbox *Per source view of band plot* controls an option to plot data for a selected (or a set of selected) source on the Band/Data plot of the session editor. If the check box is «on», a listview with names of sources will appear next to the plot, a user can select sources for which data should be displayed. However, for displays with small resolution all elements of the session editor window could not fit to a screen, in such case a user can turn off the checkbox.

When a user loads a vgosDb database providing a session name, nuSolve usually reads the lates version of a wrapper file of the database. However, sometimes it is preferrable to load the latest version produced by your analysis center even if a higher version created by another institution already exists. In this case turn on the checkbox *Load databases produced by [local] VLBI Analysis Center only*, where [local] is an abbreviated acronym of your analysis center (see subsection *4.1.3 User's identities*).

The option *Output file format for plots* tells νSolve in what format plots should be saved. Currently, the following formats are supported: PDF (vector) format and JPG, PNG, PPM (raster) formats.

And the last option, *State and intermediate results autosave mode*, specifies how frequently a procedure of autosaving have to be performed. There are three modes, *None*, *On Exit* and *Always*. The procedure stores the intermediate results and the parameterization in a separate file in the corresponding directory.

4.1.3 User's identities

To generate proper report files and reflect history of changes in the data files, a user has to provide the corresponding information. It is collected in the *User Identities* tab of the *Preferences* window, Fig. 4.3.

If you make data processing and submit your results to the IVS, you have to provide correct information in the files.

There are two groups, *User* and *Analysis Center*, that contain fields that describe a user and an analysis center.

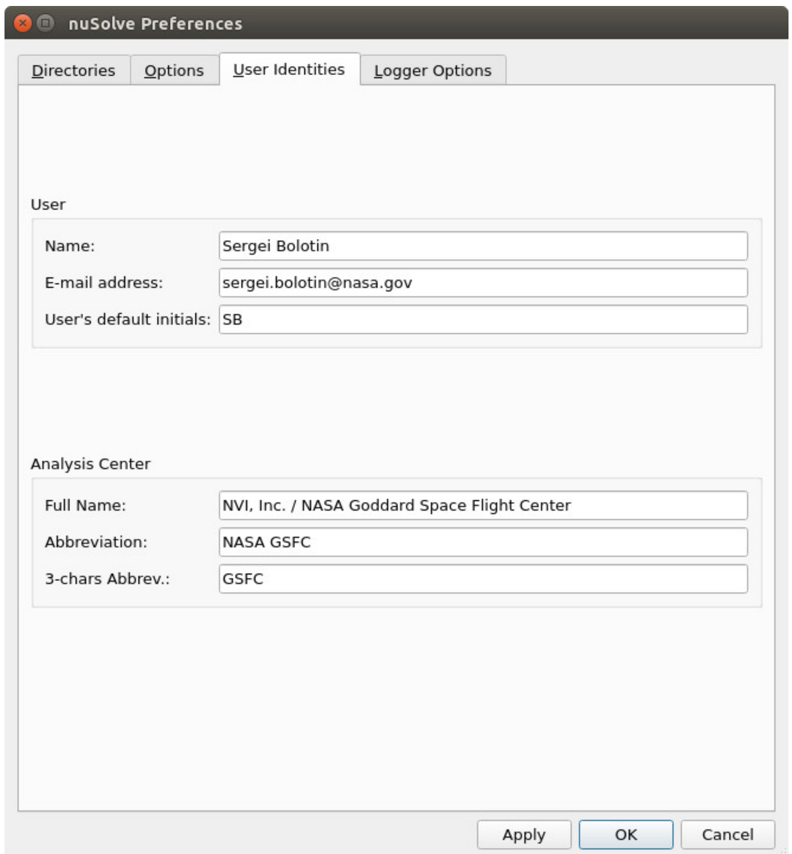


Figure 4.3: GUI to set up identities of an analysis center and a user.

The first group has full user name, user's e-mail address and initials. The name and the e-mail address will appear in the report in spool file format. The two-letter initials are the 'solve-initials', and historically are appended to a prefix *SPLF* to generate the spoolfile name, e.g., *SPLFSB* in the case as shown on the figure.

The second group contains full name of analysis center, its abbreviated form and a few-letters abbreviated acronym. The latest attribute for your analysis center can be found at

`https://cddis.nasa.gov/archive/vlbi/ivscontrol/ac-codes.txt`

If your analysis center does not have a three-letter code and you are going to participate in IVS activities, please contact `mail-to:ivscc@ivscc.gsfc.nasa.gov` to request the code.

4.1.4 Configuration of logging subsystem

The last tab, *Logger Options*, controls the logger behavior. All parts of the software communicate with a user through *logger*. The logger is a small object that accepts messages from other parts of the software and prints them on the main (=log) screen. Depending on log facility and log level a message will or will not appear on the log screen.

The group *Logger's Options* specifies a file name of the log output (*Log file name*), number of lines that will be kept on the screen (*Log capacity*), whether the log outputs should be saved at all (*Save log to the file*) and if it is desired to add a time stamp to the message (*Put time stamps*). If you want in addition to time stamp add a date too, set the checkbox *Use full date format* to «on».

WARNING: If the logger is instructed to save data in the log file, the size of the file will grow up. νSolve does not check the size of the file (it does not know about your intentions), and eventually the file could take all free space on your computer! If you do not need the log output from previous runs, please, remove the file on a regular basis.

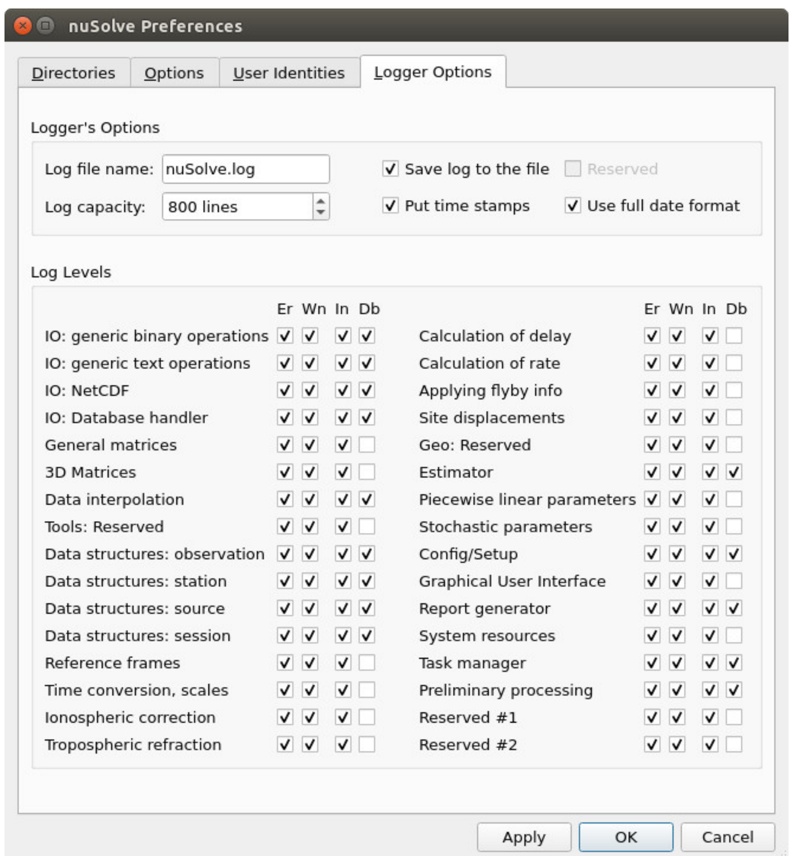


Figure 4.4: GUI to set up logger options.

Currently, there are four log levels: error, warning, informational and debug. Error messages are generated when something wrong happens and νSolve's behavior is unstable or unpredictable. Examples include missing essential files (e.g., file with VLBI observations), or an inconsistency in the data. Warnings are issued if something unexpected happened but the software is able to deal with it. For example, if a VLBI station that participates in the session was not found in the file with the external *a priori* coordinates. In this case νSolve will use coordinates from the database as *a priori*, and it notify the user about this issue. The last two log levels, informational and debug, are interesting mostly for developers.

In the group *Log Levels* one can find a table of log levels (*Er* – error, *Wn* – warning, *In* – informational and *Db* – debug) and facilities. The log facility is an integral part of the software that generates the message and most routines use this facility. Two examples are the graphical user interface or evaluation of ionospheric correction. Separation of logging output by levels and facilities allows developers to focus on some particular topic without altering other parts of the software.

4.2 Configurations of data analysis process

The second set of options, configuration, is more VLBI-centric. To get an access to the configuration, select menu *Edit–>Edit General Config* or press *Ctrl+g* keys. A dialog window that allows to change the options will appear on the screen. A similar widgets will be available on Session Editor window too with some exceptions. Some of these options specify what and how software have to act when it reads a VLBI session, these options will not be available on Session Editor window.

4.2.1 General options

The first tab of General Configure Editor window, *General*, shows general options (Fig. 4.5).

The groups *Delay type* and *Rate type* allow a user to switch between the types of observables. Currently, νSolve process single band delays, group delays, phase delays and delay rates. The use of the last two types, phase delays and delay rates, is in a preliminary stage and should be used for testing purposes mostly.

Another widget group, *Bands*, will appear on Session Edit window (see Section 6.2.2). It will display available for a particular session bands and allows a user to select an active band.

However, in practice it is not convenient to go every time to the tab *Options* of the Session Edit window and change the current observable or the active band manually. νSolve can do it automatically depending on what the user is looking at. If the check box *Active band follows tab* of the group *Interactions with GUI* is checked, then the active band will always be the band which is currently visible on the tab *Bands*. If the check box *Observable follows plot* is checked and the delay rates are not in a solution, then when a user selects single band delay residuals as the Y-axis of the plot on the tab *Bands*, νSolve will automatically set the observable to single band delays. The same is true for the group or phase delays. If a user chooses any other column as the Y-axis of the plot, the previously selected observable will not change. If delay rates are in the solution (i.e., *Rate types* are not *None*), the feature of the automatic switching of the observables is suppressed. These two check boxes are checked by default.

The software does not include in data analysis the observations with low quality code. The spin box *Observation Quality Code threshold (use obs of this code or higher)* specifies this threshold.

The check box *Interactive SOLVE compatible* assures that all calculations are done in interactive SOLVE compatible mode. It is recommended to turn this mode on.

The next check box *Estimate clock break parameters in common solution* switches a mode of treating the clock breaks. If the checkbox is «on», νSolve will estimate parameters of clock break(s) in a common solution (as interactive SOLVE does). If the checkbox is «off», the parameters of clock break(s) are estimated once and then are applied as a step wise function to the clocks of a station.

To take into account stored in a database observation elimination flag keep the check box *Use SOLVE's observation elimination flag* turned on.

There is also an option to use observations only with definitely good quality codes and then later, at the stage of outlier restoration, to add all other observations with all acceptable quality codes. This option mimics

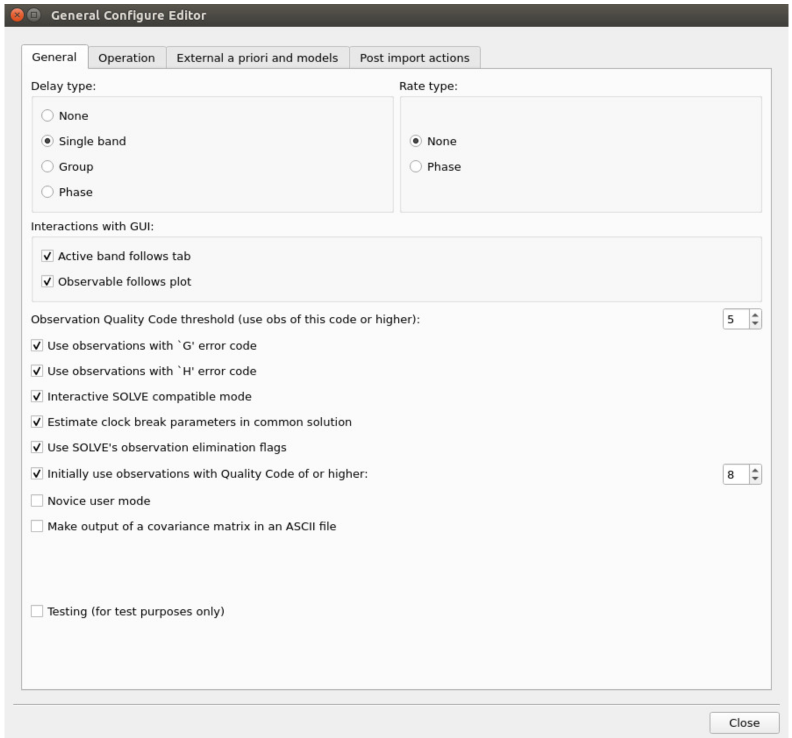


Figure 4.5: Configuration: general options.

interactive SOLVE and can be modified with *Initially use observations with Quality Code of or higher* check box and the associated spin box.

The *Novice user mode* check box turns on «Novice user» mode. The difference of the mode and the normal operation is in verification of the "accomplishments" that were done for the session before exporting data. Currently, if the mode is «on» the software checks for existence of the ionosphere corrections and reweighting before save a session. If these operations were not performed, a warning message will be issued. A user can override the warning answering *Yes*. Also, a warning message will occur if a user will try to calculate ionosphere corrections before resolving group delay ambiguities or attempt to resolve the ambiguities if the the ionosphere corrections are already evaluated.

If the checkbox *Make output of a covariance matrix in an ASCII file* is «on», a covariation matrix will be stored in the directory with spool file output in an ASCII file «PALL??» with the last two characters of user initials.

The check box *Testing (for debug purposes only)* is designed to turn on some part of code that performs a debug procedure. Do not use this feature unless you are intending to debug the source codes.

4.2.2 Run time options

This tab, *Operation* collects options that are most demanding during data analysis, Fig. 4.6.

The first group, *Parameters to Estimate*, specifies the parameters that will be estimated during data processing. The group consists of a table with the parameter names in the first column. The next five columns of radio buttons specify the type of parameter. The first type, *No* means "do not estimate a parameter". The type *Lcl* specifies estimation of the parameter based on the whole set of observations of the session. The type *Arc* treats a parameter as an arc parameter, where unbiased estimates of the parameter are made for user specified time intervals that

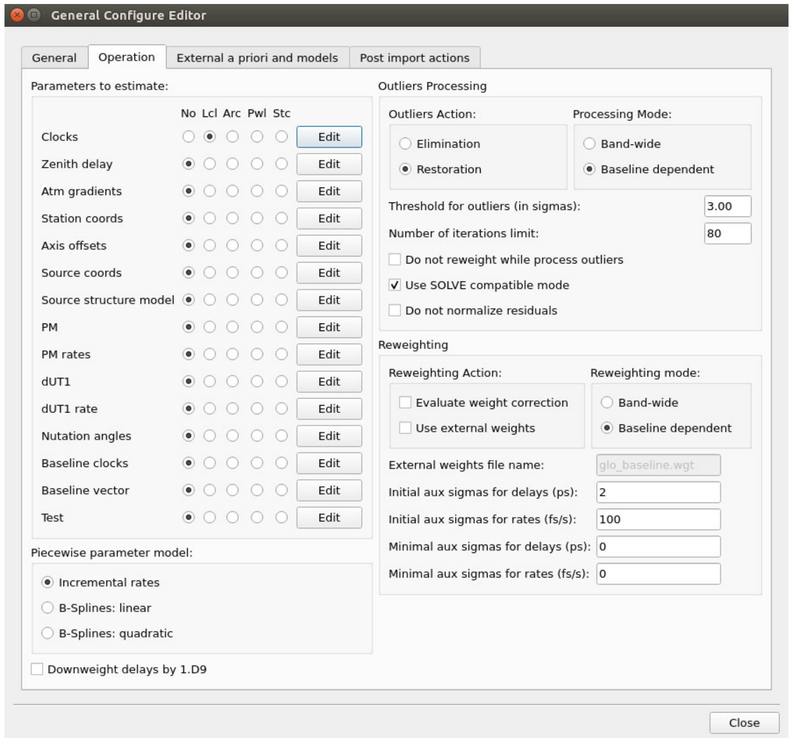


Figure 4.6: Configuration: operational options.

are smaller than a whole session length. Usually, the lengths of arcs are 1, 2 or 3 hours. A user can change the arc length for the parameter by pressing the *Edit* button in the last column (see Fig 4.7). The next type, *Pwl*, treats a parameter as a piecewise-continuous function. It is similar to the arc type but the model requires the parameter to be continuous. There are three models implemented in νSolve to deal with piecewise-continuous parameters. Two of them, incremental rates and linear B-Splines, came from CALC/SOLVE. The third model is quadratic B-Splines.

A user can change the mode of PWL parameters in the group *Piecewise-continuous parameter model* just below the *Parameters to Estimate* group. The realization with B-splines needs much less CPU time while the incremental rates mode produces results that are same as obtained with interactive SOLVE. The last parameter type is a stochastic parameter, given in the last column, *Stc*. Currently, the 2^{nd} order Markov process and its two extreme cases, white noise and random walk, are realized in νSolve. Modeling a time varying parameter as a stochastic parameter has some restrictions; this type cannot be combined with arc or PWL. Do not mix these types in a solution as the results will be unpredictable.

The checkbox *Downweight delays by 1.D9* turns on "downweighting" of the delays. When delays and delay rates are processed in one solution and this checkbox is turned «on», then effective standard deviations of delays are multiplied by 10^4 to reduce the influence of the delays in the solution. This option is taken from interactive SOLVE.

The group *Outlier Processing* determines the response of νSolve when a user presses the button *Outlr* of the Session Edit window. If *Outlier Action* is set to *Elimination*, then when the user clicks the button, the software will check the residuals and mark the outliers that are not to be used in further solutions. If the type of action is set to *Restoration*, then previously eliminated observations will be included in next solutions.

The procedure of outlier elimination or restoration is performed in the following way. Normalized residuals are calculated for a set of observations determined by the *Processing Mode* setting (for a whole band, *Band-wide*, or

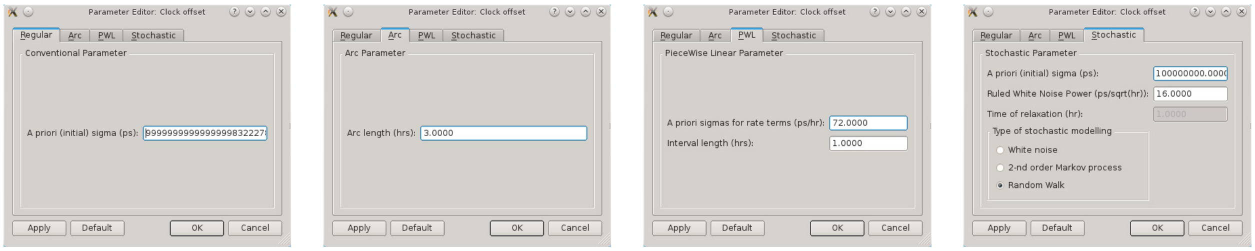


Figure 4.7: Parameter options editor: local (leftmost), arc, piecewise and stochastic (right) parameters.

for each baseline, *Baseline dependent*). Then, an observation with normalized residual greater than or less than a specified threshold (specified by the *Threshold for outliers (in sigmas)* line editor) is marked for exclusion or inclusion. In the elimination process, the software removes the observation with the largest normalized residual. Then νSolve makes an estimate of parameters and recalculates the residuals. The whole procedure is repeated several times until no observations exceed the threshold or the number of iterations exceeds the specified user limit, *Number of iterations limit*. In the restoration process, observations that were not initially included in the solution (typically because they had quality codes less than 8-9) are considered for restoration. The software includes observations of this type with the smallest normalized residuals as long as their normalized residuals were less than the specified threshold. Then νSolve estimates parameters and recalculates the residuals. The whole procedure is repeated until all observations of this type have been included. The elimination and restoration processes are repeated until no observations can be eliminated or restored. The procedure of outlier elimination is performed in conjunction with the procedure of weight corrections. To minimize the time of data processing, weight correction calculations can be skipped between iterations. This option is controlled by the *Suppress weight correction in outliers processing* check box. The check box *Process outliers in the SOLVE compatible mode* assures that the normalized residuals are evaluated in the same way as interactive SOLVE does.

The *Reweighting* group controls the process of weight correction. The weight correction calculations are performed on the fly, after the user presses the *Process* button, at the stage when new residuals are available. These calculations are relatively time consuming and by default they are turned off. Usually, we turn on evaluation of additional weights after clock breaks are fixed, ambiguities are resolved, ionospheric corrections are evaluated and large outliers are removed. The check box *Evaluate weight correction* is responsible for this. Instead of performing the reweighting computations, it is possible to use additional weights from an external file in a solution. This option is implemented mostly for compatibility with interactive SOLVE and testing purposes. There are two widgets in the *Reweighting* group: the check box *Use external weights*, which turns «on» or «off» the use of the external weights, and the *External weights file name* line editor, which allows the user to specify the file. The weight corrections can be evaluated for a whole set of observations over all baselines, which is the *Band-wide* mode, or for each baseline separately, which is the *Baseline dependent mode*. In addition, a user can specify values for initial additional weights (for delays and rates) and for minimal values of these parameters.

4.2.3 Applying different models and using external a priori information

The third tab, *External a priori and models*, specifies how the software will apply different available models and use *a priori* information from external files. This tab is shown on Fig. 4.8.

The group *Use external files with a priori info* allows a user to use *a priori* values of various parameters from external files. In general, the theoretical values and partial derivatives of observables with respect to parameters are evaluated by CALC software and stored in databases. The *a priori* which were applied in these calculations are also stored in the database. Sometimes it is convenient to use *a priori* values that are different from the initial ones. For example, suppose a station has moved due to an earthquake but CALC used station positions from an ITRF solution. In this case the actual station position will differ from the *a priori* position and this difference

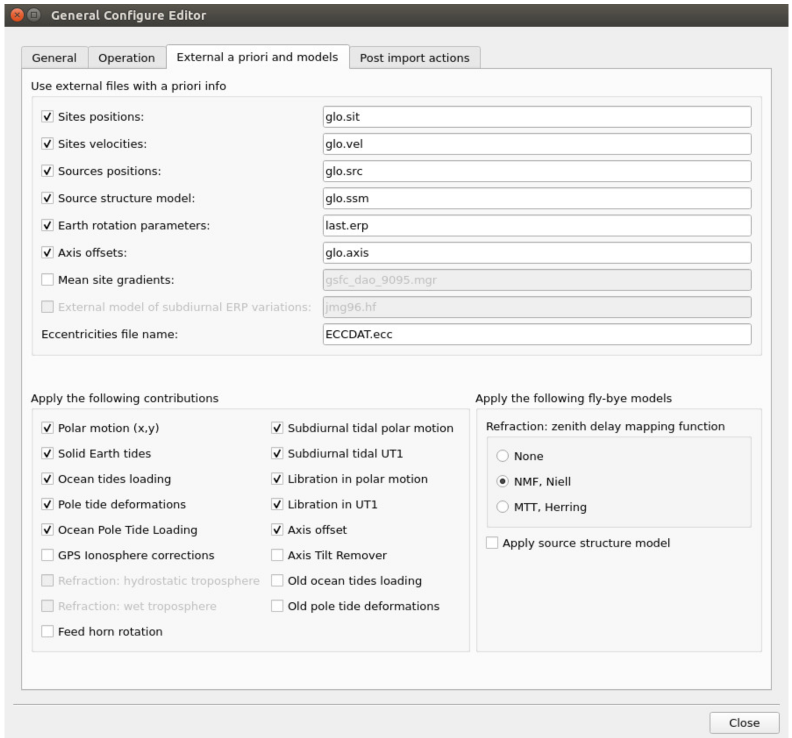


Figure 4.8: Configuration: use of contributions and external *a priori* information.

will cause an increase of residuals. Depending on the shift, the large residuals will make it impossible to resolve ambiguities (at the S-band especially) correctly and to eliminate outliers. Another case when we need external *a priori* values is when observations of new sources are included in VLBI analysis. Prior to analysis of the first few sessions with a new source, it is impossible to determine its coordinates with the necessary precision without using an approximate external *a priori* position.

All files but one mentioned in the widget group are ASCII files in the format that is used by CALC/SOLVE. If CALC/SOLVE is not installed on your computer and the user wants to apply external *a priori* values, he/she should get the corresponding file(s) from somewhere else or consult the source codes. The files are expected to be in the directory specified in *References* by *A Priori files* field. However, a user can overwrite this assumption specifying an absolute path there. The *Site Positions* and *Site Velocities* check boxes turn «on» or «off» using the external *a priori* for the corresponding parameters. The file names are entered in the corresponding line editor box. The check box *Source Positions* controls using external *a priori* values for sources coordinates. The *Source structure model* check box specifies an external file with parameters of source structure models see section *7.2 Using a source structure model* for details.

The checkbox *Earth rotation parameters* refers to polar motion (p_x, p_y) and Earth rotation $d(UTC - UT1)$. The software can read files of three types: the Earth rotation parameters (polar motion and dU1) in "ERP" file format (generated by eopkal utility from CALC/SOLVE package), the Earth orientation parameters (ERP plus the nutation angles) generated by USNO and IERS. The EOP files from USNO should be available at

`https://www.usno.navy.mil/USNO/earth-orientation/eo-products/weekly`

and mirrored at

`https://cddis.nasa.gov/archive/products/iers`

The file is called «finals2000A.data». The IERS EOP file(s) is available at

`https://www.iers.org/IERS/EN/DataProducts/EarthOrientationData/eop.html`

it is called «EOP_14_C04_IAU2000A_one_file_1962-now.txt». All three types of files are ASCII files and do not contain marks to identify the type of a file. The software assumes that file extension «.erp» specifies "ERP" format (output of eopkal), the extension ".data" means USNO generated EOP files and the extension ".txt" is for EOP IERS C04 solution. Using external a priori EOP files from USNO and IERS is in testing mode. Unfortunately, EOP from both institutions have nutation angles that are not smoothed. That make them useless in interpolation. Though, it should be ok to use such files for processing a new INT session, when the nutation angles are derived not from VLBI observations, but is a prediction.

Axis Offsets and *Mean Site Gradients* are self explanatory. The check box *External model of subdiurnal ERP variations* specifies the use of an external model of the diurnal and semidiurnal oscillations of Earth rotation parameters. If the check box is «on», νSolve will apply the external model of subdiurnal ERP variations entered in the line editor box. The last row of the widgets group allows a user to specify a file with stations eccentricities.

The next group, *Apply the following contributions*, specifies which effects should be used in data analysis. By *contribution* we mean the impact of some geophysical effect on the predicted values of observables. The CALC software evaluates delays and delay rates by applying some standard models. Other standard models are also evaluated and stored in the database, but are not added to the precalculated values. Moreover, some alternative models are evaluated and stored in the database. CALC/SOLVE (and νSolve) takes into account a model by adding the corresponding contribution. To apply an alternative model, the applied contribution should be subtracted and an alternative contribution added to precalculated observables. Some of contributions listed in *Apply the following contributions* are necessary to obtain a solution, e.g., polar motion or solid Earth tides. Others are required to get a «standard» solution. Few contributions are added for testing purposes or should be used in rare cases. One of the contributions, *GPS Ionosphere corrections* is provided by external software. The list of available contributions is determined by current version of CALC. Two checkboxes, *Refraction: hydrostatic atmosphere* and *Refraction: wet atmosphere*, works in a different way: if a checkbox is turned «on», then the contribution stored in a database will be used. If the checkbox is set to «off», the corresponding values will be calculated by the software on fly.

The widget group *Apply the following fly-by models* allows to a user to control models that will be calculated by νSolve and applied during analysis of observations (on the fly). A user can specify what zenith delay mapping function should be used: NMF [6] or MTT [5]. To use or not a model of source structure effect is controlled by a check box *Apply source structure effect*. For the source structure effect a particular source should have parameters of the model in the corresponding external file (see above) and the source needs to be configured to use the model (see below, subsection *6.2.5 Tab «Sources (List)»*).

4.2.4 Configuring post import actions

The rightmost tab, *Post import actions*, specifies what procedures should be called after successful reading of a VLBI session. Configuration of the procedures are network dependent. The software separates all existing VLBI sessions by «network» type. For each type of network a user can set up its individual configuration. νSolve determines the network type of a session by consulting an appropriate masterfile. If νSolve is unable to determine the network type of a session, it will use *DEFAULT* set up, as it shown on Fig. 4.9. Also, if a configuration for the network type of the session was not set, the *DEFAULT* set up will be used. Currently, the set of network types and theirs attributes are hard coded into the software and cannot be modified by a user.

To select a type of a VLBI network, click on a combobox labeled *Set up for network ID*. All available VLBI network names will appear in a list of the combobox.

The checkboxes in the widget group *Actions to perform* specify what procedures will be automatically called after a session has been read.

The first action, *Perform set up of the session*, assigns a reference clocks status to one of the stations, turns off a «estimation of station positions» flag for one of the stations (by default this flag is «on» for all stations)

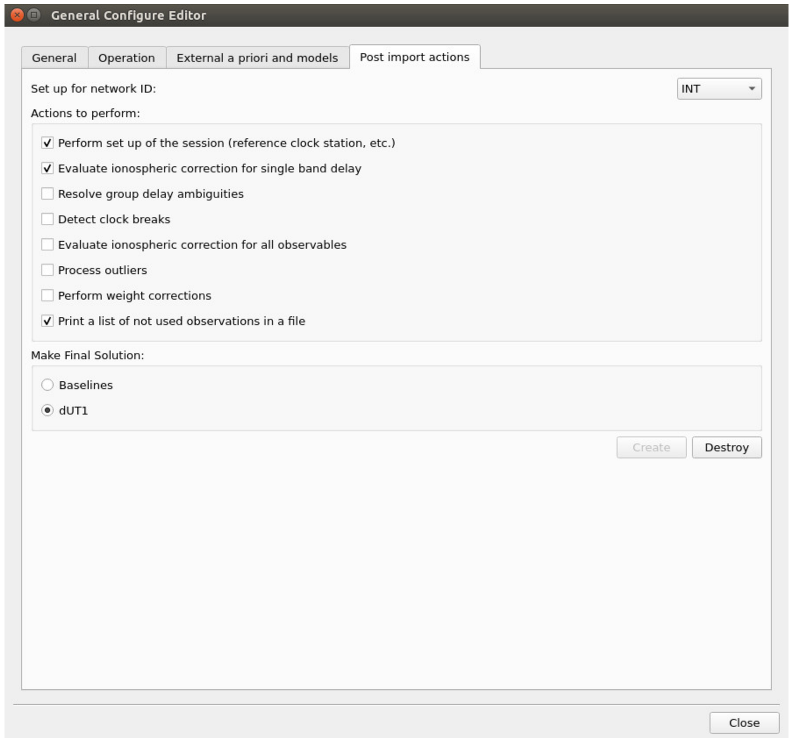


Figure 4.9: Configuration: set up of post import actions.

and checks the history part of a database trying to figure out for which station manual phase calibrations were applied and, if found, turns the attribute *use cable calibration* «off» for such station.

The second action performs calculation of ionospheric corrections for the single band delays only.

The first two post-import actions are useful for data analysis of practically any session, therefore they are turned «on» for *DEFAULT* set up.

The rest of actions are designed for automatic process of intensive sessions (e.g., IVS-INT1, IVS-INT2, IVS-INT3). We do not recommend use them for other type of VLBI sessions. These actions are self explanatory.

The last action, *Print a list of not used observations in a file*, toggles creation of a file with a list of all observations that are not in the last solution. The file has a name «nuSolve_unused_observations_??» where the last two chars are user's initials, it is placed in a directory specified in software Preferences (see Subsection 4.1.1).

The group *Make Final Solution* allows a user to select which type of solution should be used for evaluation of weight corrections. The standard practice for processing intensive sessions is to estimate clock parameters and zenith delays of observing stations and changes of Earth rotation, $d(UT1-UTC)$. However, there are cases when either Earth orientation parameters are not known correctly or *a priori* station positions differ form the actual ones. In these cases it is possible to estimate baseline vectors instead of $d(UT1-UTC)$. This type of solution will absorb deviances of *a priori* EOP or station positions so it will make possible to deselect outliers and evaluate realistic weight corrections.

The software does not keep configurations for all networks. In the beginning, there are two sets of configurations, one is for *INT* sessions and another one is *DEFAULT*. A user can add a set up for some particular VLBI network by choosing the network in the combobox *Set up for network ID* and then clicking a button *Create*. After that, when a configuration has been created, a user is able to modify the actions. To delete existing set up, press a button *Destroy*. The *DEFAULT* configuration is not possible to delete.

Chapter 5

Plotting subsystem

To visualize and edit sets of data we developed a small and simple plotting subsystem (or plotter). Since the plotter appears in various parts of data analysis procedure and has the same controls, we discuss it in this separate section.

The plotter (Fig. 5.1) consists of a canvas, where the data are plotted, and controls, that are widgets that allow a user to modify how and what part of data will be plotted. In addition, a user can interact with the canvas too to make selections or deselections and get information about the data. Also, the plotter emits signals as a reaction to the user pressing keys, so it is possible to plug in external functionality.

In general, the plotter accepts multiple sets of data in the same format. Each set of data (called here *branch*) is plotted with the same color. If the user decides to make a plot with connected lines, points of each branch will be linked separately. Each point on the canvas is represented by a vector of dimension 2 or higher. Each element in the vector is considered as having the same property (physical meaning, units, etc.) for all points. For examples, one vector could consist of delay and sigma. Not all data is expected to have corresponding sigmas. Some of elements can be assigned a special property and will have special treatment. E.g., if the software sets a Type_MJD attribute, then the plotter will treat that data as time in MJD scale and put proper labels (if this element is set to be the x-coordinate).

The current distribution of νSolve has the ability to test the plotting subsystem. Select menu *Test–>Test Plotter* to invoke a window with some artificial data. On the plot there are four branches labeled *Branch #1*, which consists of time-tags, *Branch #2*, *Branch #3* consist of data with corresponding sigmas, and *Interpolation #2* is a cubic spline interpolation of *Branch #1*.

5.1 Plotter controls

The plotter controls (Fig. 5.2) are the following widgets: selection of axis to plot, list of branches, selection of how to plot the data (with points, lines, errorbars or impulses (lines from the X-axis to the point), modifying colors of the branches (hue, saturation and value), altering ranges on the plot, scaling and output controls.

5.1.1 Axes to plot

The widget *Axis to plot* allows user to select X- an Y- axis from provided data. There are two comboboxes which show labels of the available data. A user can select each of elements of data format as X- or Y-axes on the plot. As an example, on the Fig. 5.3 the left screenshot demonstrates user selection of Y-axis the third column of data format. On the right screenshot one can see a function of the third column, titled *Value #2*, as a function of the second column, *Value #1*.

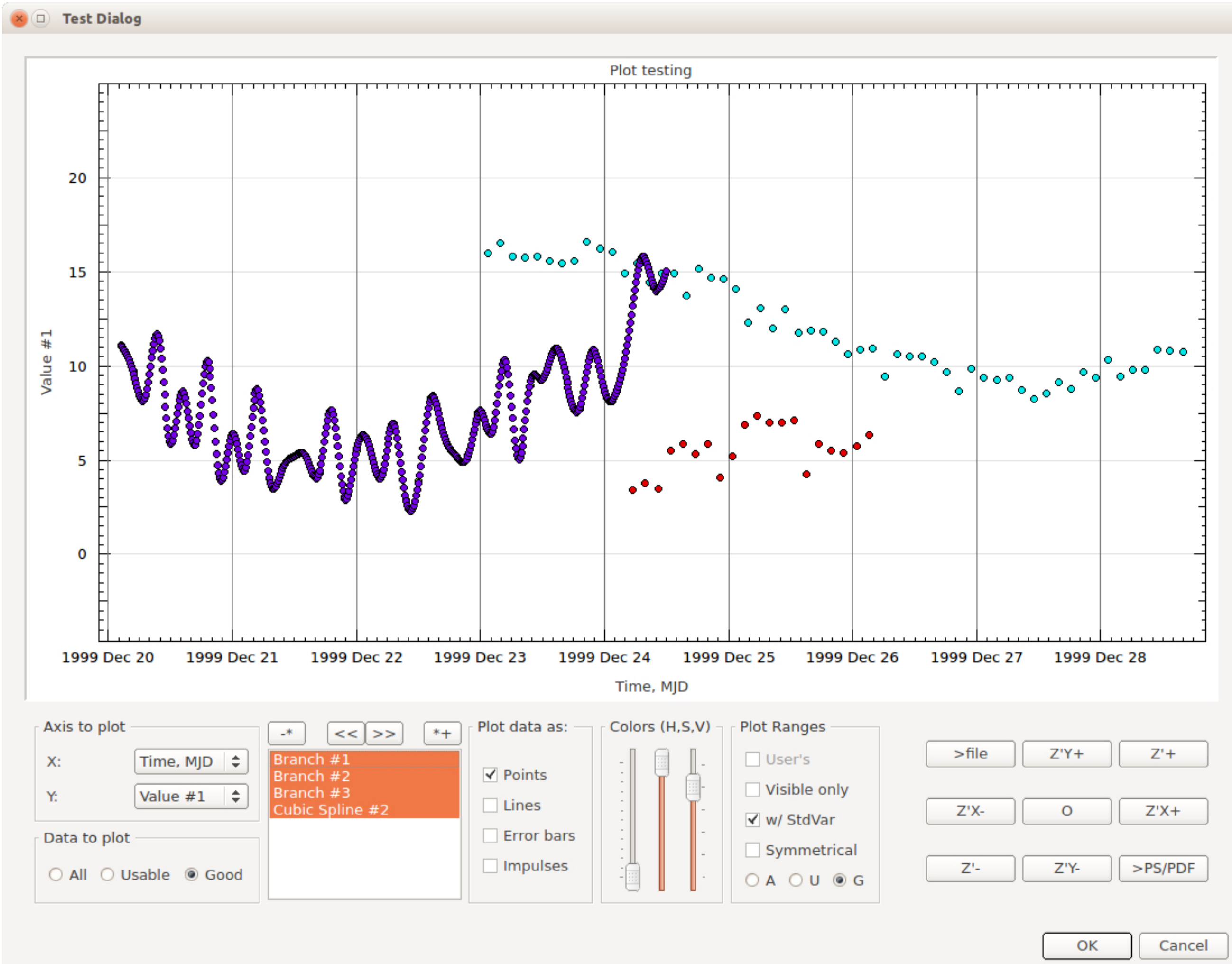


Figure 5.1: Test plot.

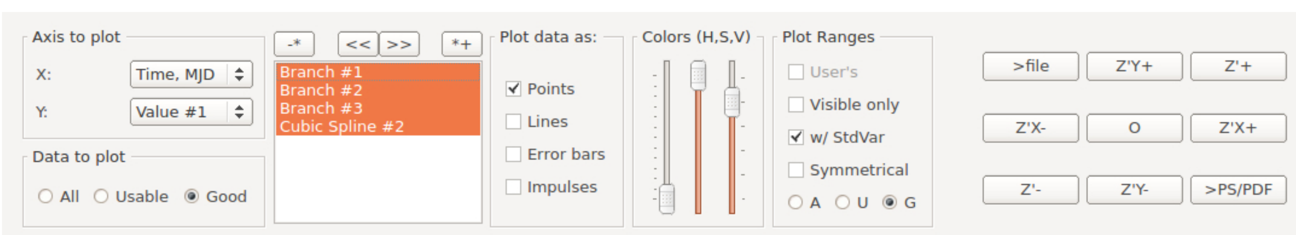


Figure 5.2: Plotter controls.

5.1.2 Branches

The list of branches makes possible to select or deselect on the plot some particular branch. The Fig. 5.4 demonstrates a selection of various branches on the plot. Also, there are two buttons: -* unselects all branches;

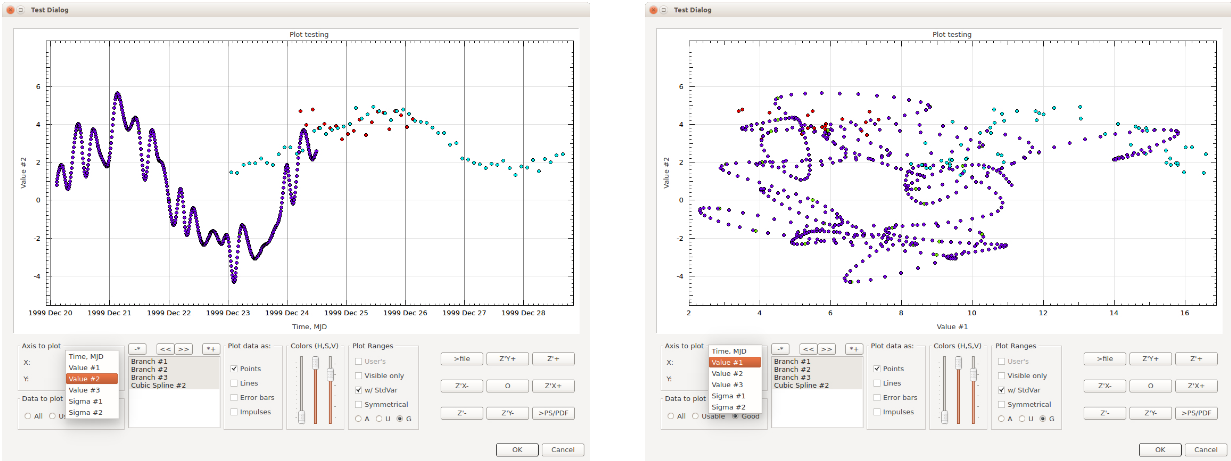


Figure 5.3: Selection of axis to plot.

and *+ selects all branches. There are a couple of other buttons, « and », that allows a user to traverse through branches going forward or backward one branch at a time.

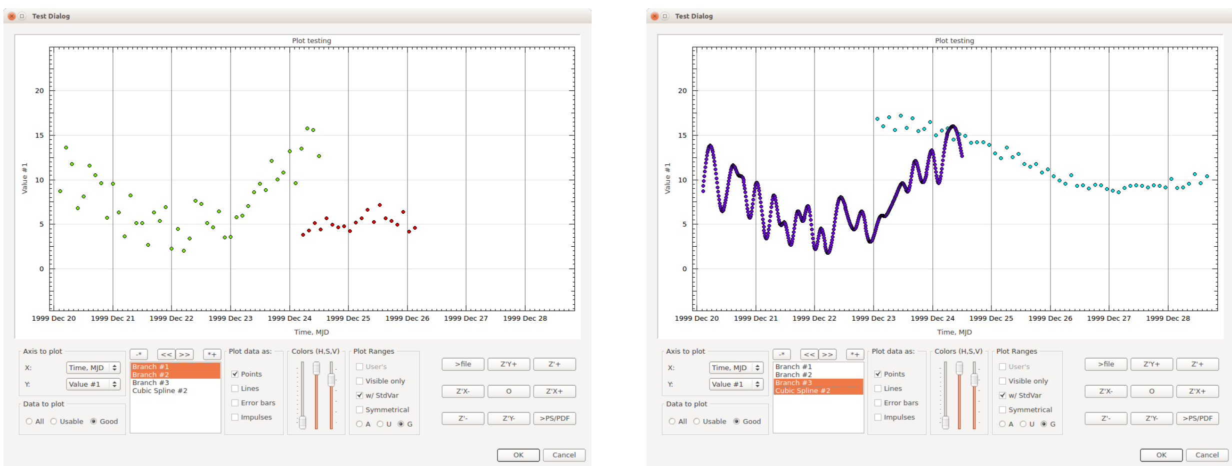


Figure 5.4: Selecting branches at the plot.

5.1.3 How to plot data

The group *Plot data as* contains several checkboxes that specify how to plot the data. Now it is possible to display data as points, lines, errorbars and impulses. All modes are independent and can be mutually combined.

5.1.4 Altering colors

Branch colors are assigned automatically, using HSV scheme. To modify hue phase, saturation and value of the colors, use the slide bars from the group *Colors (H,S,V)*.

5.1.5 Range controls

The group *Plot Ranges* controls how the plot ranges are calculated. The check box *User defined* becomes available if a user specifies the plot ranges manually. To return back to automatic plot range mode, uncheck this button. Current data model assumes that there are two kind of points, «good» and «discarded». By default, only «good» points are plotted. To display all points on the plot, check on the box *All Data*. In this case all data will be displayed and the plot ranges will be adjusted to make the «discarded» data visible too. The check box *Relaxed* turns on calculation of the plot ranges only for selected branches. And the check box *w/ StdVar* includes standard variations of the values in the calculation of the plot ranges.

5.1.6 Scale and output controls

The last group of plotter controls contains a set of buttons that perform the following functions. The rightmost top and leftmost bottom buttons, *Z'+* and *Z'-* change the scale of whole plot in one or another direction. The user can perform the same operations using their mouse wheel (if their mouse has a wheel, of course.)

The rightmost and leftmost middle buttons, *Z'X+* and *Z'X-* change the scale of X-axis on the plot. The keys *Ctrl+RightArrow* and *Ctrl+LeftArrow* do the same.

The middle top and bottom buttons, *Z'Y+* and *Z'Y-* (as well as keys *Ctrl+UpArrow* and *Ctrl+DownArrow*) change the scale of Y-axis on the plot.

The central button, *O*, restores the altered scales.

Pressing the button *>file*, a user can save data (only selected branches) as ASCII files for further processing. The format of the files is simple, three columns, X, Y and standard variations of the Y column. The button *>PS/PDF* makes an output of the plot in Postscript or PDF format.

5.2 Canvas

The canvas also provides user controls. The communication between user and canvas is performed by processing signals from a pointer device (a mouse).

Clicking the left mouse button when the cursor is on a point selects this point. The selected points are displayed as open circles. A click on a selected point discards the selection.

Clicking the right button of the mouse pointing anywhere on the canvas displays the plot coordinates of the pointer location.

To select a group of points, hold the left mouse button down and drag the mouse over the points, generating a rectangular area containing the selected points (see Fig. 5.5). All points that appear inside this area will be marked as selected points. To remove selection marks from a group of points, first, press the *Shift* key and then hold down the left mouse button and drag the mouse to create the area where all marked points will be deselected. In both cases, the status of already altered points does not change. For instance, if you make a selection, all previously selected points will not became unselected and vice verse.

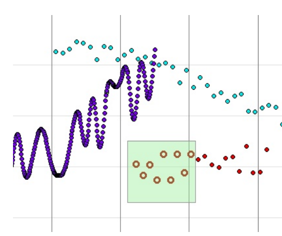


Figure 5.5: Selection of points on the plot.

By pressing and holding the *Shift* key, clicking the right mouse button, and dragging the mouse, you can measure a distance on the plot between two points. The *Shift* modifier is necessary only when you press right mouse button, you can release the *Shift* key, it does not affect the measurement mode. Fig. 5.6 shows how a user can acquire the distance between two points on the plot.

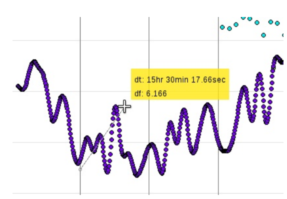


Figure 5.6: Selection of points on the plot.

Using the *Ctrl* key and holding the right mouse button allows the user to select a plotting range by dragging the mouse over a selected area, thereby switching to manual range mode. When the user releases the right mouse button, the ranges will be taken from the selected area and applied to the plot. In contrast to the previous mode, the

Ctrl key must be pressed when the mouse button is released, otherwise the operation will be discarded. The Fig. 5.7 displays the operation of changing the ranges. In the left panel, a user selects the new ranges by dragging the mouse. The right panel shows the plot with new ranges.

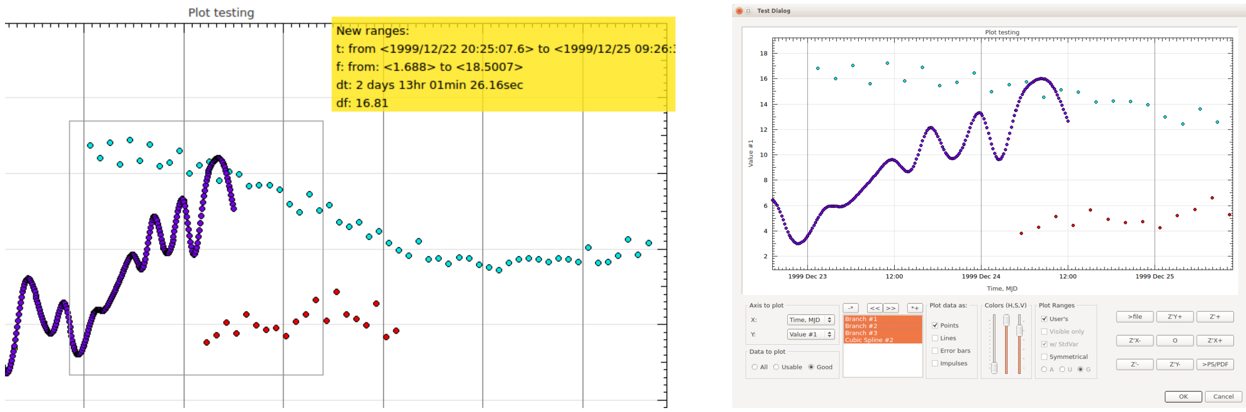


Figure 5.7: Changing ranges of the plot. Selecting new ranges (on left) and resulted plot with the new ranges (on right).

When the plotter switches to the manual range mode, the checkbox *User defined* in the group *Plot Ranges* on the plot window page becomes available for user interaction and its status becomes «on». To return back to the automatic range mode (where the software will evaluate ranges from the available data), just uncheck the checkbox.

Chapter 6

Overview of the Session Editor window

The Session Editor window is a primary tool for processing a VLBI session. In this section we will review the essential parts of the window and describe its interface with a user.

6.1 Reading a session

To invoke the Session Editor, the user must open an existing VLBI session.

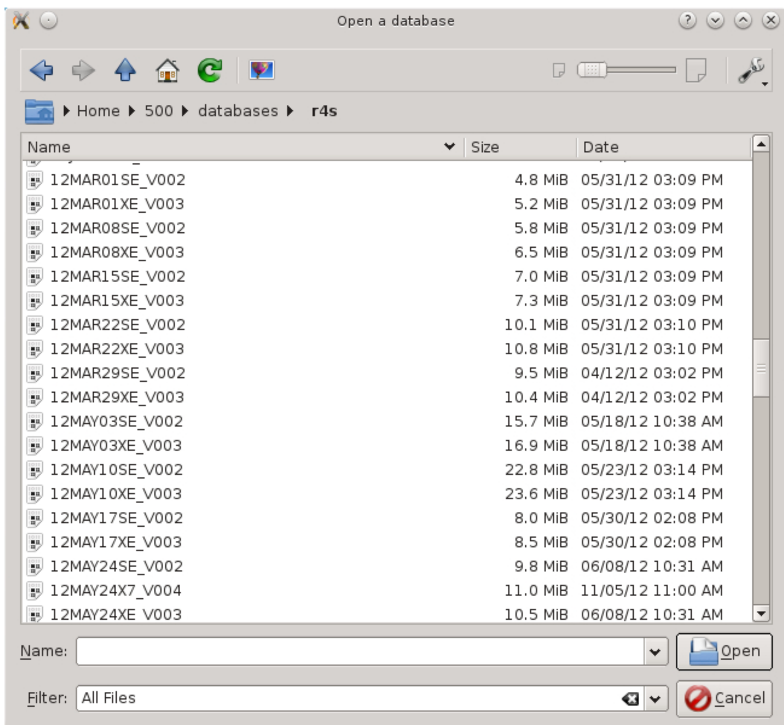


Figure 6.1: Opening a VLBI session in the standalone mode.

The software can import a VLBI session in three formats, DBH, vgosDb and vgosDa (formerly known as AGV format, see http://astrogeo.org/gvh/vda.html).

To read a session in DBH format, press *Ctrl+e* or select menu *Edit–>Edit Session (DBH)*. Depending on the software operation mode, standalone or working through catalog, a dialog window will pop up.

In the standalone mode the dialog window is a Qt's standard file selection dialog window, Fig. 6.1.

The directory where it starts is taken from the preferences, *Observations (DBH) files*, however, a user can search through whole file system to pick up a file. The user selects a file for the session to be opened. Since a multiband VLBI session is represented by at least two databases, generally, one for X-band and another one for S-band, the software will automatically pick up a corresponding file with another band (if it exists). If several files of the appropriate band exist, the software will pick the file with the closest (but not larger) version number of the file specified by a user.

In the catalog aware mode, the user enters the database name in a simple window (see Fig. 6.2).

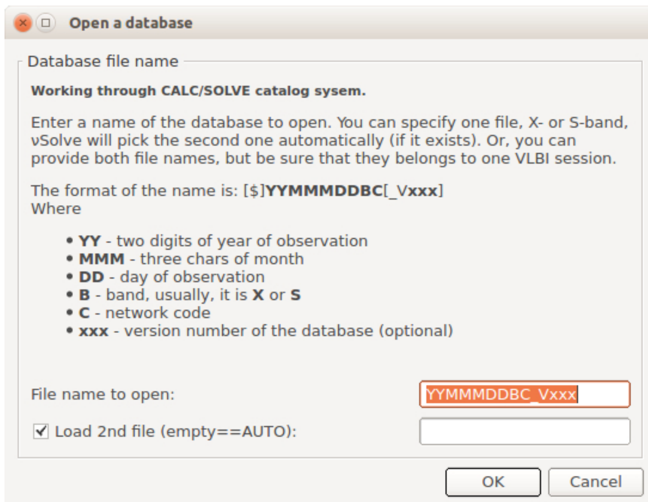


Figure 6.2: Opening a VLBI session in the CALC/SOLVE catalog aware mode.

A database name is expected to follow the standard IVS naming convention. Optionally, a version (in the standard form) can be specified. If a file for a different band exists in the catalog, it will be loaded automatically. To prevent automatic loading of the second band database, set the checkbox *Load 2nd file* to «off». If a second band database has an alternate name, you can specify it in the field of *Load 2nd file*. If the field is empty, the name of the second band database will be figured out by the software using the IVS naming convention.

The software will check database for the available versions and if the next version is already registered in the catalog, it will issue a warning about the inability to save the database as a new version. In this case, the user can save his work, but before saving it, he should remove the database with new version from the catalog manually before saving the data.

There are two options to read a session in vgosDb format. The first one allows a user to chose a wrapper file manually. The main menu option *Edit->Open Wrapper file (vgosDB)* or key combination *Ctrl+o* invokes a standard file dialog to select a desired wrapper file.

The second option chooses the latest wrapper file from a database name. Press *Ctrl+Shift+o* keys or select *Edit->Open Session (vgosDB)* from the main menu, a simple dialog window will appear and a user can provide a name of a database. If the desired session exists in the standard place, νSolve will read it.

To read a file in vgosDa format, press *Ctrl+Shift+a* keys or select *Edit->Open VDA file*.

6.2 Session Editor

After reading a database for a VLBI session, a Session Editor window will appear, as in Fig. 6.3. This is a central window for processing a VLBI session. The user can open as many windows as his/her computer virtual memory allows. The user can open the same session in several windows since the windows do not share the same data. However, in the catalog aware mode saving the data will be possible only if the corresponding version is available in the catalog. In the standalone mode, if a database with new version already exists, the file name of the saved data will be altered.

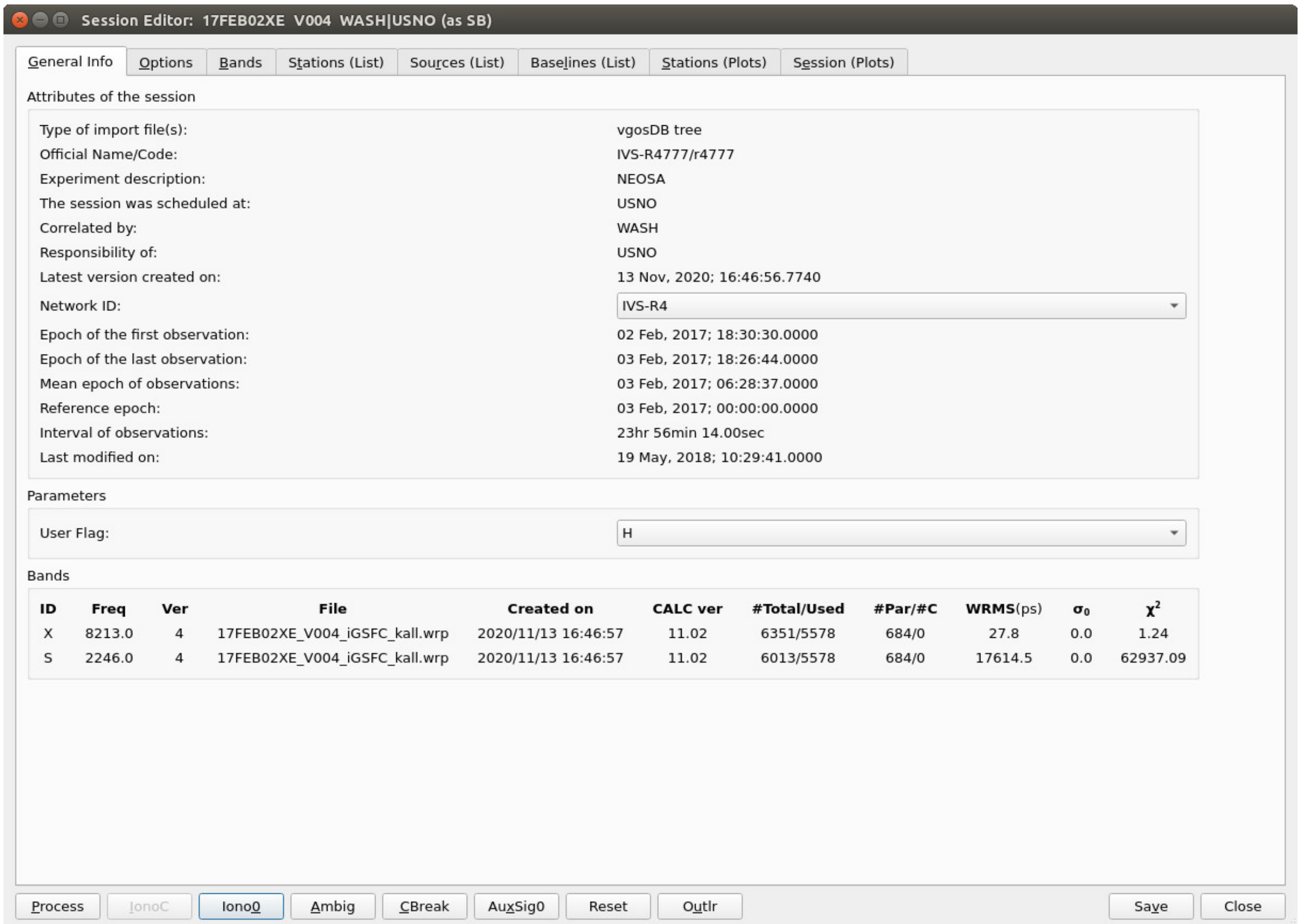


Figure 6.3: Session Editor window, general info.

The Session Editor window consists of several tabs along the top of the window and a row of buttons along the bottom. The *General Info* tab provides general information about the session. From the *Options* tab the user can find controls to choose options for how to process a session. The *Bands* tab refers to separate bands in order to display of selected data as plots, allow control of band-specific parameters, etc. The tabs *Stations (List)*, *Sources (List)* and *Baselines (List)* make it possible to manipulate data using the stations, sources or baselines attributes. The *Stations (Plots)* tab displays station-dependent data. The last tab, *Session (Plots)*, is designed to test Earth rotation parameters that are estimated as arc, PWL or stochastic parameters. It is currently in a test mode and will be discussed in the next release of the software.

Pressing one of the buttons causes νSolve to perform some particular action. The button *Process* performs one iteration of parameter estimation. *IonoC* evaluates ionospheric corrections and *Iono0* discards these corrections (sets them to zero). The button *CBreak* initiates a procedure of clock break detection. To perform an outlier processing action the user should press the *Outlr* button. To resolve ambiguities,the user would press the *Ambig* button. The button *AuxSig0* sets to zero any previously evaluated weight correction sigmas.

The user saves an updated session in a file on the hard drive by pressing the button *Save*. The button *Close* will close the Session Editor window. If the preferences check box *Warn me when closing Session Editor Window* is «off», the window will close without any warnings and if there were unsaved data (the autosave mode in Preferences was set to *None*), it will be lost.

The button *Reset* clears all editing information. A VLBI session will look like newly arrived from a correlator.

In addition to buttons, there are shortcuts (combinations of keys) that invoke actions. For example, if the user presses the *Ctrl+r* keys, νSolve will generate a report in a CALC/SOLVE spoolfile format (by default, such a report is generated when a user saves a processed VLBI session). The list of available key combinations is in Table 6.1. Some of the shortcuts will be discussed later.

Shortcut	Action
Ctrl+a	Exports estimated source positions and station coordinates (aposteriori info) with applied velocities in a format of the a priori files.
Ctrl+b	Process a clock break for the marked observation.
Ctrl+f	Generate a list of commands to refringe marked observations.
Ctrl+g	Store a VLBI session in vgosDa format.
Ctrl+h	Creates ASCII files with results of estimation the stochastic parameters.
Ctrl+i	Displays a window with lists of unusable and excluded observations.
Ctrl+n	Exports a VLBI session in NGS format.
Ctrl+r	Generates a report in a CALC/SOLVE spoolfile format.
Ctrl+Shift+r	Generates a report in a CALC/SOLVE spoolfile format. In addition, prints the residuals and other information to the spoolfile.
Ctrl+s	Saves the intermediate results in a file.
Ctrl+t	Performs a test of an action, for test purposes only.
Ctrl+z	Creates ASCII files with values of total zenith delays.
Alt+2	Makes two consecutive iterations of parameter estimation. The same as two clicks on *Process* button.
Alt+3	Makes three consecutive iterations of parameter estimation.
Alt+4	Performs outlier processing and then calls three iterations of parameter estimation. Equivalent to click on *Outlr* button and then *Alt+3* shortcuts.

Table 6.1: Shortcuts of Session Editor window.

6.2.1 Tab «General Info»

From the *General Info* tab, the user can find various attributes of the session. In most cases, the names of attributes are self explanatory, see Fig. 6.3. A user should ignore *User Flag* (in *Parameters* group) since this refers to future features that have not been implemented.

The group *Bands* displays available bands, their parameters, the number of all and processed or «good» observations (the column *#Total/Used*), the number of estimated parameters and applied constraints (the column *#Par/#C*), and the overall weighted root-mean- squared (the column *WRMS(ps)*) of the delay residuals for each band. The last two columns of the group show the sigma for weight correction (the column σ_0), where this value is non zero if weight corrections have been performed in the band-wide mode, and a value of the reduced χ^2 of the residuals for each of the bands.

6.2.2 Tab «Options»

The tab *Options* was discussed in details in Section 4.2. There are few exceptions: some widgets have different layout and the tab *Post import actions* of *Options* is not shown.

6.2.3 Tab «Bands»

The tab *Bands* consists of several embedded tabs (Fig. 6.4), that allow the user to display a relatively large amount of data on one screen. The main purpose of this tab is represent observations and baseline dependent values as plots. It also allows the user to edit data.

Starting with version 0.7.0 of the distribution the tab has an ability to filter data on per source basis (if the corresponding option of Preferences is selected). On the right of the tab there is a listview widget that contains names of sources. A user can select or deselect sources, the plot displays data only for sources that are highlighted in the listview widget.

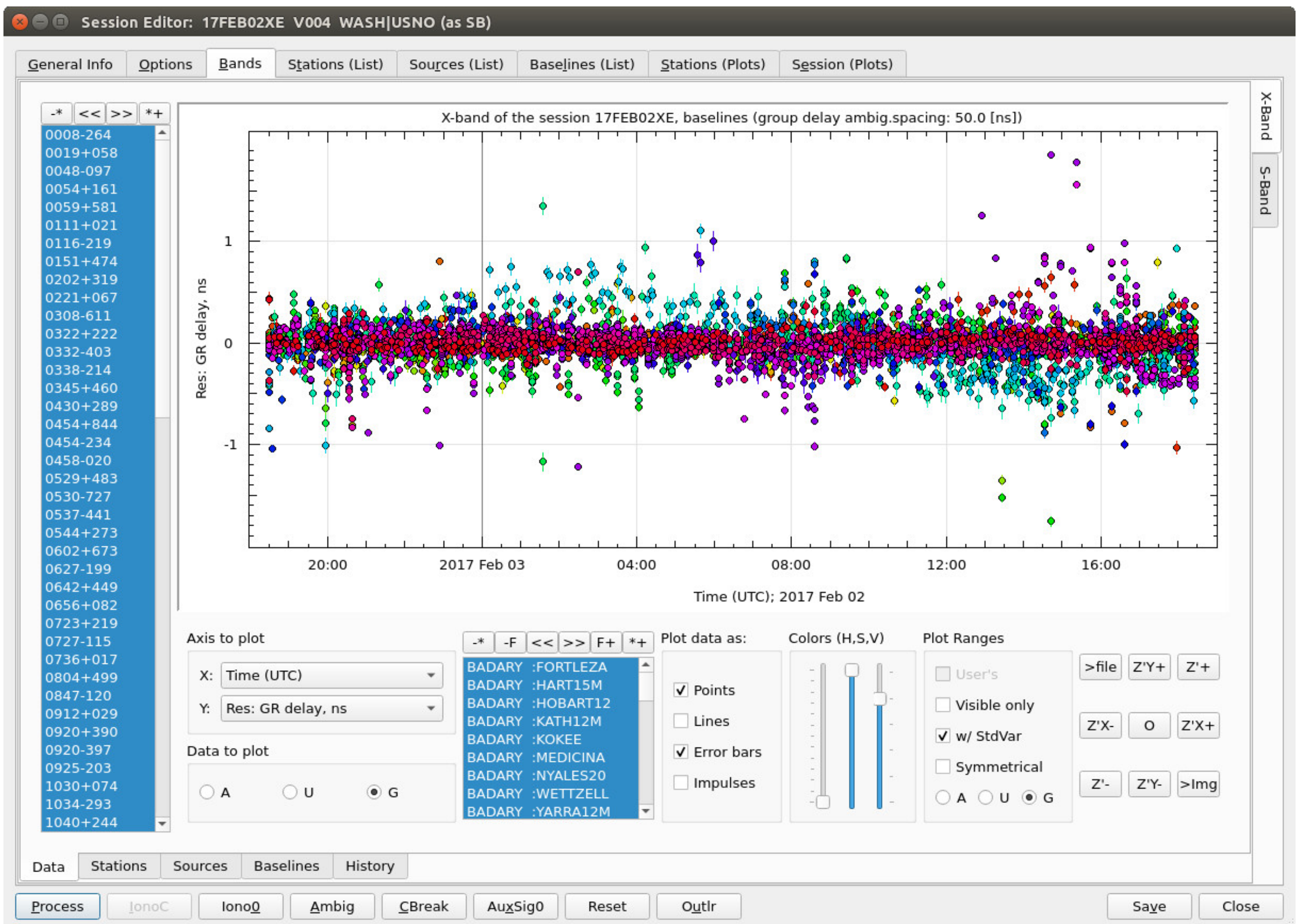


Figure 6.4: Session Editor window, band dependent plots and attributes.

At the bottom of the plot there are tabs that display information about the particular band. The tab *Data* shows plots. The tabs *Stations*, *Sources* and *Baselines* displays statistics (number of total observations, number of used observations, dispersions, additional sigmas and residuals for delay and rate) per station, source and baseline respectively. In addition, in the tab *Stations*, the user can add or modify band-dependent clock breaks for some particular station. Also, the tab *Baselines* displays ambiguity spacings and typical numbers of channels.

The interface of the last three tabs are the same as for corresponding objects of the whole VLBI session. They will be discussed later.

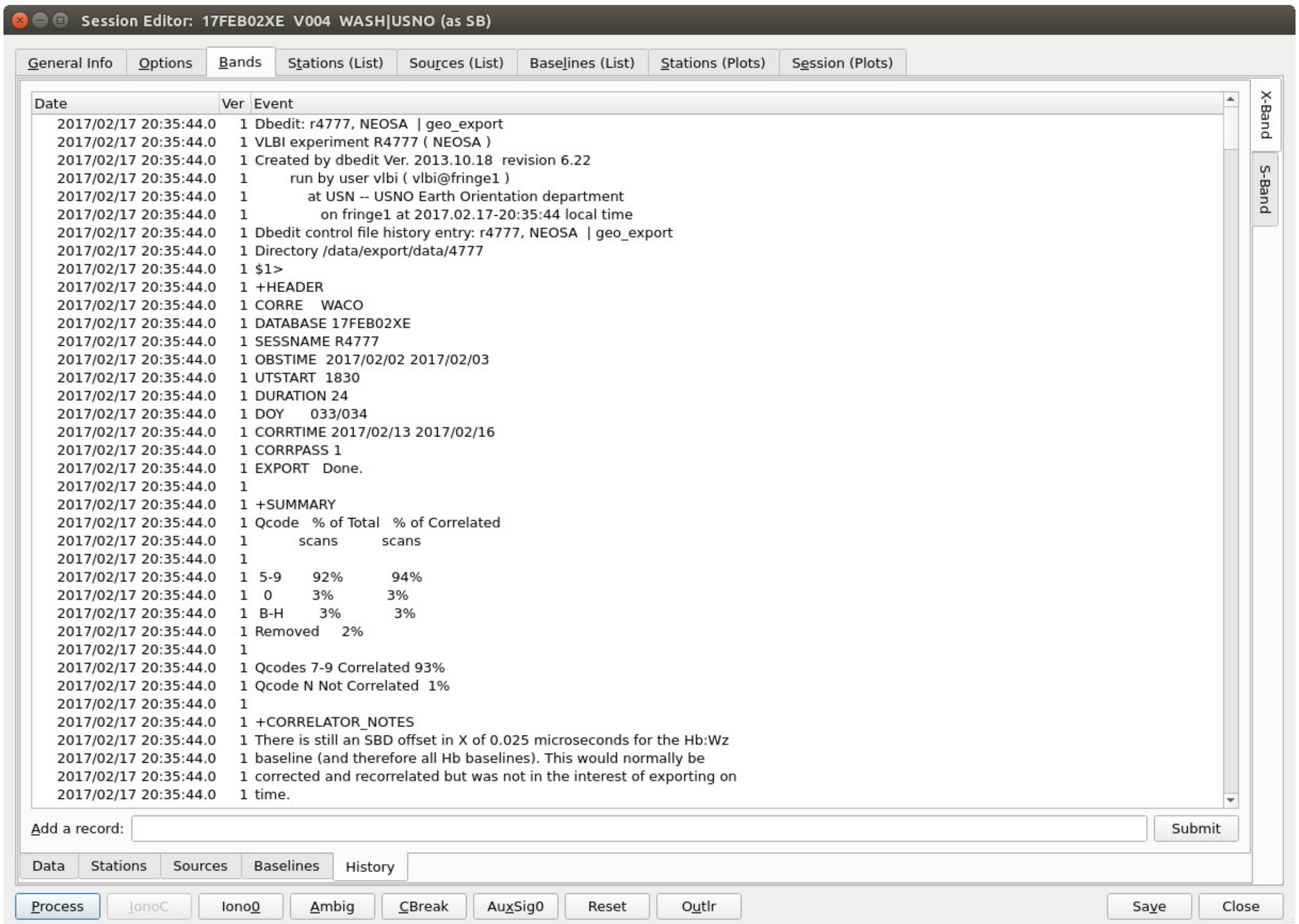


Figure 6.5: Session Editor window, history records for the band.

The tab *History*, Fig. 6.5, presents the history records from the history part of a database file. It also allows the user to add comments about processing a session (history records) manually.

Plots in the *Data* tab display baseline dependent values, such as residuals, ionospheric corrections, etc. Each baseline on the plot is represented by a branch of the plotter system. In the list of branches there are two additional buttons, *–F* and *F+*. The buttons activate filters that will be applied to the list of baselines to select, *F+*, or deselect, *–F*, some particular baselines.

A left mouse click on the button invokes a local menu with a list of stations. By selecting one of the stations, the user can select or deselect all baselines with this station.

The right mouse click invokes a menu with stations as the first or second station in the baseline. For example, if the user makes a right mouse click on the button *F+* and selects *KOKEE:* from the menu, then all baselines where the KOKEE station is the reference site will be selected.

A left mouse click on the button *F+* when a *Shift* key is pressed invokes a menu with a list of sources. If a user selects a source from this menu, all observations (currently visible or not) will be highlighted as open circles (selected). The same click on the button *–F* will deselect previously selected observations with the source from the menu.

The radio buttons at the bottom of the widget group *Plot Ranges* control ranges of plots to display data: used in the latest solution (G – good observations), potentially usable but deselected by a user or outlier elimination procedure (U – usable observations) and all available (A) observations. What subset of data to display on plots is switched by radio buttons in the widget group *Data to plot*.

The plotters of the *Data* tabs have their own sets of shortcuts. When the user selects one or several points, pressing the *Ctrl+x* key combination removes the marked point(s). Removing points means that these observations will not be used in data analysis. In this case a flag «do not use» is raised for the points. To discard the flag, user should turn on the checkbox *All Data* of the group *Plot Ranges* of plotter; then all unselected points will appear gray. Then, select the points and press the *Ctrl+y* key combination. The latest operation does not force an observation into analysis, there can be other criteria that remove observations from analysis (e.g., low quality factor).

Another operation that can be applied to selected points, are for increasing (key "=") or decreasing ("–") the number of ambiguities. In these cases the number of ambiguities are increased or decreased by one and the residuals for the group band delays are adjusted using values of the ambiguity spacing.

The key combination *Ctrl+b* is used to process a clock break in a semi-automatic mode (see the next section).

A double click on an observation point opens an observation information window, Fig. 6.6. The window is modal, i.e., it blocks access to other windows of the software. To continue, press the button «Ok».

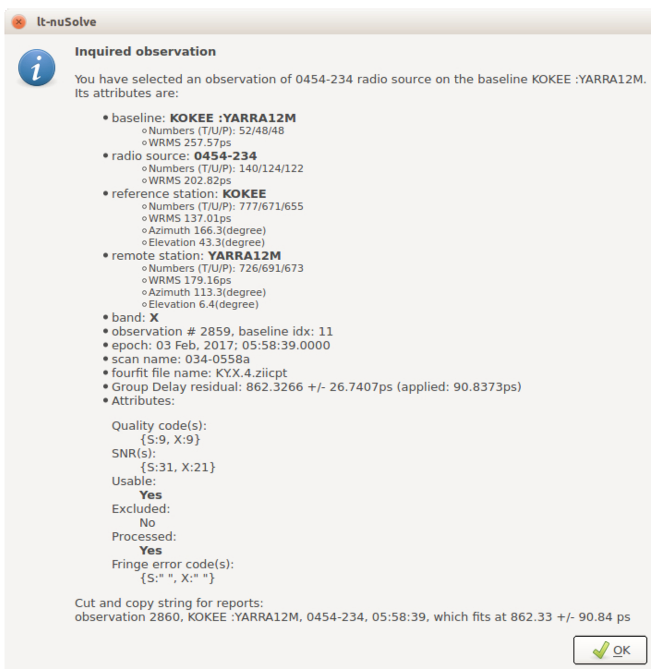
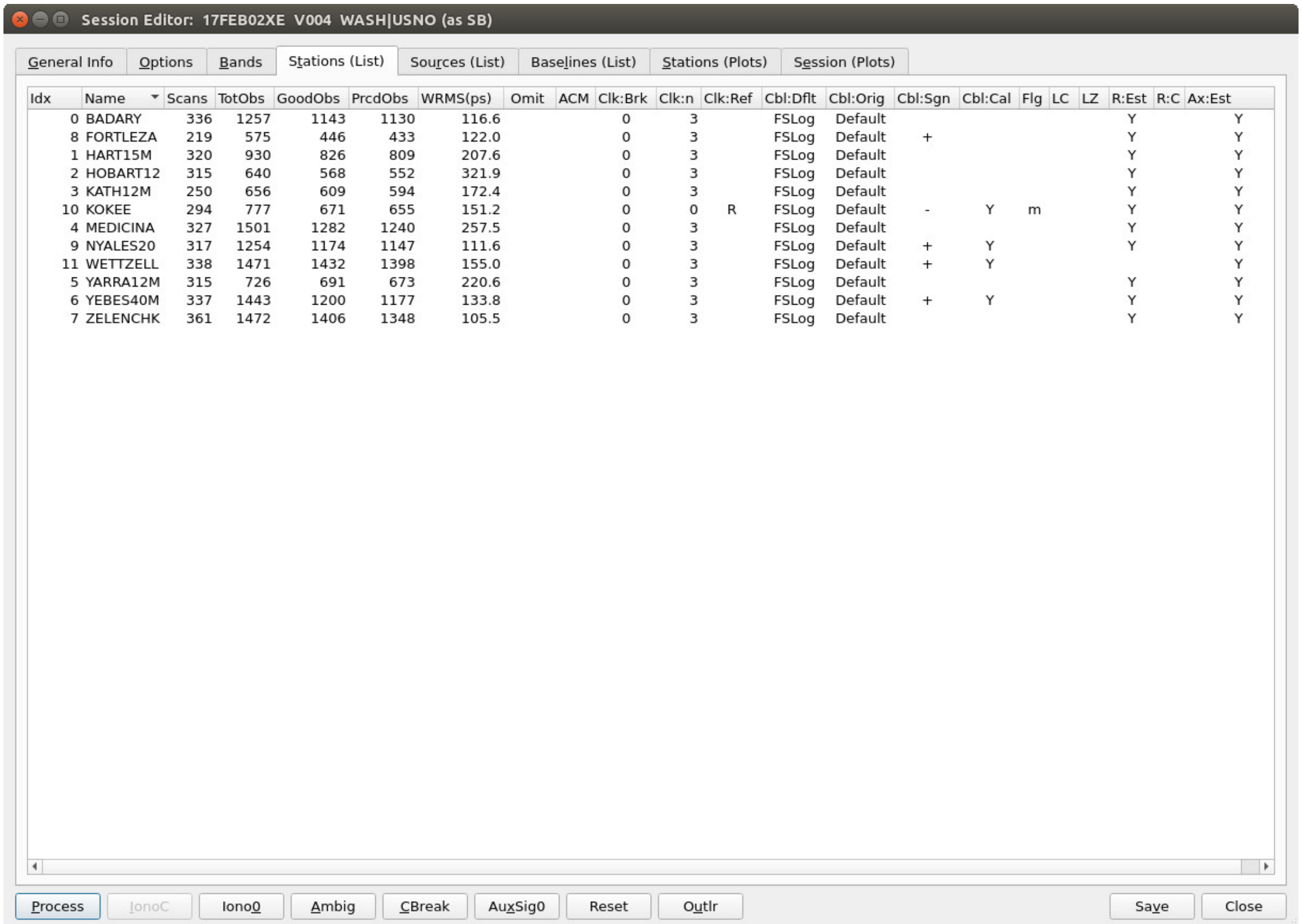


Figure 6.6: Session Editor window, the observation info window.

This window displays source and stations names, statistical information (numbers of good, usable and processed observations and WRMS for delays) for the baseline, the source and each of stations. Also, there are information on delay residual value, its standard deviations, and the applied standard deviations (which is usually bigger than the standard deviation of the delay). If an observation considered as «unusable», there will be a reason of such decision: low quality code, deselected station, source or baseline, missed observation on another band (if ionospheric corrections are evaluated), and so on.

6.2.4 Tab «Stations (List)»

The tab *Stations (List)* shows properties of the stations. It organizes them as a table, as in Fig 6.7. A mouse click on the header of the table sorts the whole table by fields in this column.



Idx	Name	Scans	TotObs	GoodObs	PrcdObs	WRMS(ps)	Omit	ACM	Clk:Brk	Clk:n	Clk:Ref	Cbl:Dflt	Cbl:Orig	Cbl:Sgn	Cbl:Cal	Flg	LC	LZ	R:Est	R:C	Ax:Est
0	BADARY	336	1257	1143	1130	116.6			0	3		FSLog	Default						Y		Y
8	FORTLEZA	219	575	446	433	122.0			0	3		FSLog	Default	+					Y		Y
1	HART15M	320	930	826	809	207.6			0	3		FSLog	Default						Y		Y
2	HOBART12	315	640	568	552	321.9			0	3		FSLog	Default						Y		Y
3	KATH12M	250	656	609	594	172.4			0	3		FSLog	Default						Y		Y
10	KOKEE	294	777	671	655	151.2			0	0	R	FSLog	Default	-	Y	m			Y		Y
4	MEDICINA	327	1501	1282	1240	257.5			0	3		FSLog	Default						Y		Y
9	NYALES20	317	1254	1174	1147	111.6			0	3		FSLog	Default	+	Y				Y		Y
11	WETTZELL	338	1471	1432	1398	155.0			0	3		FSLog	Default	+	Y						Y
5	YARRA12M	315	726	691	673	220.6			0	3		FSLog	Default						Y		Y
6	YEBES40M	337	1443	1200	1177	133.8			0	3		FSLog	Default	+	Y				Y		Y
7	ZELENCHK	361	1472	1406	1348	105.5			0	3		FSLog	Default						Y		Y

Figure 6.7: Session Editor window, list of stations.

The following station attributes are available: The number of scans, *Scans* the total, potentailly usable and processed number of observations made by a station, *TotObs*, *GoodObs* and *PrcdObs*. Residuals of group, single band or phase delays for a station are in *WRMS(ps)* column.

The column *Omit* displays a flag if a station is deselected from data analysis. The user can set this flag by clicking the mouse button with the mouse pointer in this column. If the station is turned off, a char *X* will appear in this column. The user can click and drag the mouse pointer to select/deselect a group of stations.

The column *ACM* indicates the stations with a priori clock model. Sometimes, station clocks could have a large offset, one or more seconds. It is recommended to add a priori clock model for such case otherwise global SOLVE will be unable to process a session. The column *Clk:Brk* represents numbers of clock breaks per each station. The number of polynomials in the polynomial model for the clock function are in the column *Clk:n*. The left mouse button click decreases the number and the right button increases it. The user can click and drag the mouse pointer to decrease/increase the number of polynomials for a group of stations. The reference clock flags are displayed in the column *Clk:Ref*. A mouse button click toggles this flag. If you do not assign a reference clock status to any stations, the standard deviations of clock parameters will be on the level of their *a priori* sigmas (i.e., very big). Also, you can set the number of polynomials of a reference station to zero, in this case the clock model for that station will not be estimated. If the *Clk:n* is greater than zero and the reference clock flag is set, then νSolve will apply constraints to clock parameters of the station. Usually, for a regular VLBI session there should be only one reference clock station. However, in rare cases a network can contain two separate subnetworks. In such a case, you have to assign two reference clocks, one from each separate subnetwork.

The column *Cbl:Dflt* contains information about origin of default cable calibration corrections for a station. There can be the following values in the column: *N/A*, *FSLog*, *CDMS* and *PCMT*. The default cable calibration corrections corresponds to the standard cable corrections that are in the database and are using by all data analysis software. In addition, the utility vgosDbProcLogs can collect and store cable calibration data from other sources (if they are available). For test purposes, nuSolve can use these types of data too (instead of default). What type of cable calibration origin to use is spacified in the column *Cbl:Orig*. If more than one type of data is available, a user can change the origin of cable calibration corrections using the station attributes editor window (see below). The next column, *Cbl:Sgn*, shows what sign has been applied to cable calibration readings for each station (see vgosDbProcLogs User Guide).

The column *Cbl:Cal* shows whether the cable calibration data from each each station are used or not. In general, we use cable calibration data. However, if the correlator applied manual phase calibration, then we normally do not use the cable calibration data. Also, some stations provide cable calibration data that degrade the solution. To turn off cable calibration data for some station, click the mouse button in the column.

The *Flg* column is designed to display various station flags. This column currently shows the following station flags: "do not estimate zenith delay" and "wrong meteo parameters". For test purposes there is the ability to turn off zenith delay estimation for some particular station (see below). In this case a *-Z* will be shown in the column. If a flag "wrong meteo parameters", *m*, is set, νSolve uses standard atmospheric temperature, pressure and relative humidity instead of what is present in a database.

It is possible to override parameters set up for clock and zenith delay of a station. In general, a user configure estimated parameters in the tab *Options*. Sometimes, it is necessary to alter the configuration of the parameter for some particular station. Most frequent use of this feature – large variations of clocks during one session. In this case we loose the constraints that are applied to the piecewise-continuous parameter of the estimated clocks of the station. The columns *LC* and *LZ* show flags of use of local clocks and local zenith. If for some station one of the columns has the character *Y*, a station specific configuration of the estimated parameters will be applied for the station. A user can adjust parameters of local clocks or local zenith delay with the station attributes editor window (see below).

The column *R:Est* displays which station positions will be estimated if the user decided to estimate station positions on the *Options* tab. The character *Y* means that the particular station's coordinates will be estimated if the user set the radio button of *Station Coordinates* on the *Options* tab to anything except *No*. This column only sets the status of this flag; it does not turn «on» or «off» the estimation of station positions.

A mouse click in the *R:C* column triggers the flag for a station to participate in the equations of constrains. For example, if the user wants to estimate EOP, source coordinates and station positions, then he/she must apply the No-Net-Translation and No-Net-Rotation constraints to the stations coordinates. All stations that have a * mark in this column will be involved in equations of constrains. If no stations are marked, the equations of constrains will not be applied.

And the column *Ax:Est* controls for which station(s) the axis offset will be estimated if a user decided to estimate axis offsets (on the tab *Options*). By default, for all stations this flag is turned «on».

Station Attributes Editor

A double mouse click in the area bounded by columns *Idx* and *Clk:Brk* invokes a station attributes editor window (see Fig. 6.8). This window allows a user to add, modify or delete clock break events and turn «on» or «off» all

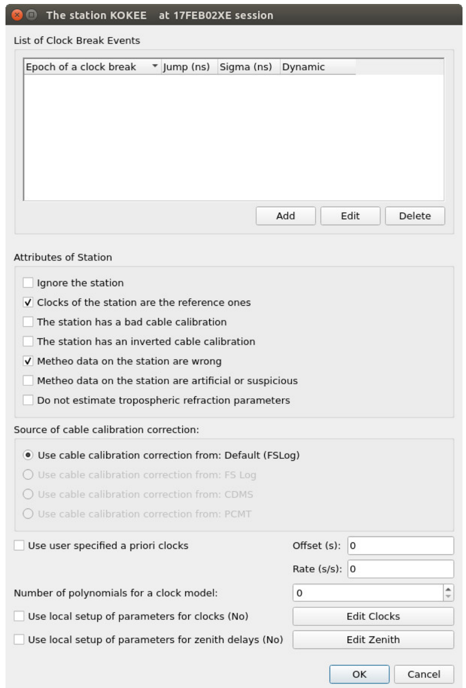


Figure 6.8: Station attributes edit window.

available stations attributes (some of them are accessible from the station list, some are not).

The upper group of widgets allows the user to edit clock break data for stations. The group consists of the list of clock breaks and three buttons. In general, clock breaks occur infrequently and the list is often empty. But if there is a break, νSolve can apply it in automatic, semi-automatic and manual modes. The first two modes will be discussed in the next chapter. In manual mode, the user must explicitly specify the information about clock breaks. To do so, click the *Add* button and a clock break editor window will appear (it will be described latter). To alter the parameters of a clock break, highlight the break in the clock break list and press the *Edit* button. The last button, *Delete*, removes a selected clock break from the list.

The lower group represents all available station attributes (some of them can be altered by interacting with the stations list). Currently there is just one station attribute that can be altered only with this window, *Do not estimate tropospheric refraction parameters*. If the corresponding check box is «on», then the tropospheric zenith delay and its gradients for this particular station will be excluded from the list of estimated parameters when the user tells the software to estimate them.

The widget group *Source of cable calibration correction* allows a user to change a type of cable calibration correction (if data are available). Using the value "Default" corresponds to data that are in the Cal-Cable*.nc netCDF file.

To add *a priori* clock offset and rate, turn «on» the checkbox *Use user specified a priori clocks* and provide values of the offset and the rate in the corresponding fields. This option is implemented for consistency with global SOLVE.

The check boxes *Use local setup of parameters for clocks* and *Use local setup of parameters for zenith delays* indicate that νSolve should apply a unique parameter set up for station clocks and zenith delays. To change the set up (by default it is the same as for all stations), click the button *Edit Clocks* or *Edit Zenith*.

Clock Break Editor

Currently, there are two approaches to deal with clock break effects in νSolve. The first one, dynamic, is in introducing additional polynomial terms of a clock function after the break has happened. The terms are estimated along with other parameters in a common solution. In this case we need only an epoch of the clock break. This method is realized in CALC/SOLVE too.

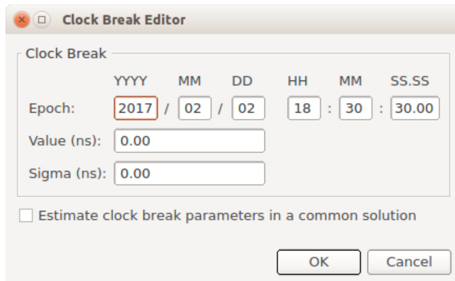


Figure 6.9: Station clock break parameters edit window.

The second approach consists in applying piecewise-continuous function to clocks of a station. The parameters of the function are estimated in a separate solution. Breaks between steps of the function absorb the effect of clock breaks. Currently, only an offset is used in the clock break function. In contrast to the previous approach, it requires the determination not only of the approximate epoch of the clock break, but, also its magnitude. On the other hand, in some rare cases, when a station has multiple clock breaks over short intervals, it allows such observations to be used in the data analysis.

The clock break editor is invoked when a user clicks the *Add* or *Edit* button in the widget group *List of Clock Break Events* (see above). The edit window, Fig. 6.9, allows a user to add or edit the epoch of the clock break (year, month, day, hour, minute and second) and the its magnitude. The checkbox *Estimate clock break parameters in a common solution* switches the type of a clock break. A user can modify a type of a particular clock break, it is ok for the software to have different types of clock breaks for one session.

6.2.5 Tab «Sources (List)»

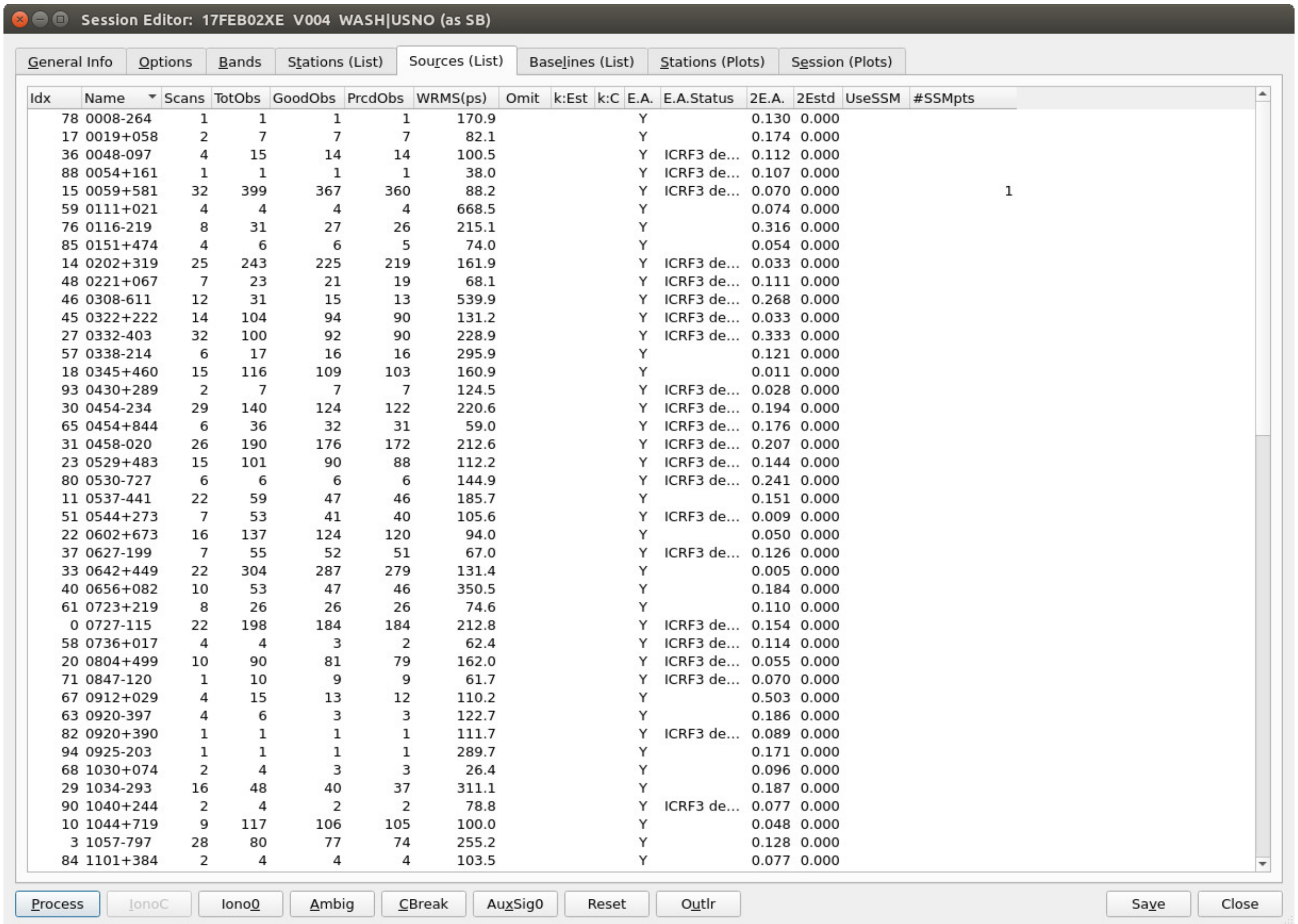
The tab *Sources (List)* shows the attributes of the sources that were observed during a VLBI session. The list has the same organization as the station list. The following source attributes are displayed: names of sources are shown in the column *Name*. The second column, *Scans*, shows total number of scans of a radio source. The column *TotObs* represents the total number of observations of a source. The numbers of potentially good observations for each source are represent in the column *GoodObs*. The number of analyzed observations of a source is in the column *PrcdObs*. Residuals of the group or single band delays for the source are in the *WRMS(ps)* column.

In the same way as for the stations list, the user can exclude particular sources from the analysis by clicking in the *Omit* column. If the source is marked for exclusion, the *X* character will appear in the column.

The column *k:Est* represents the "estimate the source position" attribute. Again, as for stations, this flag does not turn on or off the estimation of source coordinates. It only tells whether a source's position will be estimated or not. Now, by default, all sources are turned off from the estimation.

Also, a combination of estimated parameters may require applying constraints for the estimated source positions (e.g., when positions of all available stations, coordinates of sources and EOP are turned on). To select which source will be included in No-Net-Rotations constraints click in the column *k:C* for the selected sources. The character * will mark sources that will be constrained.

Traditionally, interactive SOLVE and νSolve use source coordinates from external a priori files. If a source is not present in such file, the a priori values that were provided by CALC will be used. If the column *E.A.* contains



Idx	Name	Scans	TotObs	GoodObs	PrcdObs	WRMS(ps)	Omit	k:Est	k:C	E.A.	E.A.Status	2E.A.	2Estd	UseSSM	#SSMpts
78	0008-264	1	1	1	1	170.9				Y		0.130	0.000		
17	0019+058	2	7	7	7	82.1				Y		0.174	0.000		
36	0048-097	4	15	14	14	100.5				Y	ICRF3 de...	0.112	0.000		
88	0054+161	1	1	1	1	38.0				Y	ICRF3 de...	0.107	0.000		
15	0059+581	32	399	367	360	88.2				Y	ICRF3 de...	0.070	0.000		1
59	0111+021	4	4	4	4	668.5				Y		0.074	0.000		
76	0116-219	8	31	27	26	215.1				Y		0.316	0.000		
85	0151+474	4	6	6	5	74.0				Y		0.054	0.000		
14	0202+319	25	243	225	219	161.9				Y	ICRF3 de...	0.033	0.000		
48	0221+067	7	23	21	19	68.1				Y	ICRF3 de...	0.111	0.000		
46	0308-611	12	31	15	13	539.9				Y	ICRF3 de...	0.268	0.000		
45	0322+222	14	104	94	90	131.2				Y	ICRF3 de...	0.033	0.000		
27	0332-403	32	100	92	90	228.9				Y	ICRF3 de...	0.333	0.000		
57	0338-214	6	17	16	16	295.9				Y		0.121	0.000		
18	0345+460	15	116	109	103	160.9				Y		0.011	0.000		
93	0430+289	2	7	7	7	124.5				Y	ICRF3 de...	0.028	0.000		
30	0454-234	29	140	124	122	220.6				Y	ICRF3 de...	0.194	0.000		
65	0454+844	6	36	32	31	59.0				Y	ICRF3 de...	0.176	0.000		
31	0458-020	26	190	176	172	212.6				Y	ICRF3 de...	0.207	0.000		
23	0529+483	15	101	90	88	112.2				Y	ICRF3 de...	0.144	0.000		
80	0530-727	6	6	6	6	144.9				Y	ICRF3 de...	0.241	0.000		
11	0537-441	22	59	47	46	185.7				Y		0.151	0.000		
51	0544+273	7	53	41	40	105.6				Y	ICRF3 de...	0.009	0.000		
22	0602+673	16	137	124	120	94.0				Y		0.050	0.000		
37	0627-199	7	55	52	51	67.0				Y	ICRF3 de...	0.126	0.000		
33	0642+449	22	304	287	279	131.4				Y		0.005	0.000		
40	0656+082	10	53	47	46	350.5				Y		0.184	0.000		
61	0723+219	8	26	26	26	74.6				Y		0.110	0.000		
0	0727-115	22	198	184	184	212.8				Y	ICRF3 de...	0.154	0.000		
58	0736+017	4	4	3	2	62.4				Y	ICRF3 de...	0.114	0.000		
20	0804+499	10	90	81	79	162.0				Y	ICRF3 de...	0.055	0.000		
71	0847-120	1	10	9	9	61.7				Y	ICRF3 de...	0.070	0.000		
67	0912+029	4	15	13	12	110.2				Y		0.503	0.000		
63	0920-397	4	6	3	3	122.7				Y		0.186	0.000		
82	0920+390	1	1	1	1	111.7				Y	ICRF3 de...	0.089	0.000		
94	0925-203	1	1	1	1	289.7				Y		0.171	0.000		
68	1030+074	2	4	3	3	26.4				Y		0.096	0.000		
29	1034-293	16	48	40	37	311.1				Y		0.187	0.000		
90	1040+244	2	4	2	2	78.8				Y	ICRF3 de...	0.077	0.000		
10	1044+719	9	117	106	105	100.0				Y		0.048	0.000		
3	1057-797	28	80	77	74	255.2				Y		0.128	0.000		
84	1101+384	2	4	4	4	103.5				Y		0.077	0.000		

Figure 6.10: Session Editor window, list of sources.

a char "Y", the corresponding source is present in the a priori file. The column *E.A.Status* contains a comment string from the a priori file.

A length of arc between source a priori position that was used by CALC and the value from the a priori file is displayed in the column *2E.A.*. The units are milliarcseconds.

A length of arc between source a priori position and its estimated coordinates (if source positions were estimated) is shown in the column *2Estd*.

The last two columns characterize use of a source structure model. The column *UseSSM* displays for which source the model should be applied (a character «Y»). A number of secondary components of the model is shown in the column *#SSMpts*. The section *7.2 Using a source structure model* discuss details of the model application.

Source Attributes Editor

A source attribute editor can be invoked by a double mouse click in the area bounded by columns *Idx* and *Wrms(ps)*. In the same way as for a station it allows a user to adjust available source attributes and edit parameters of the source structure model (see section *7.2 Using a source structure model* for details).

The upper group of widgets allows a user to edit the source structure model. The group consists of the list of model components and three buttons. If no model was defined for a specified source, the list will be empty.

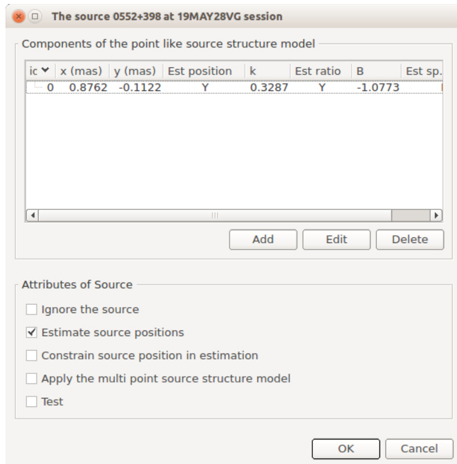


Figure 6.11: Source attributes edit window.

To add a component of the model, click the *Add* button and a component editor window will appear (see next subsection). To alter the parameters of a component, highlight it in the list and press the *Edit* button. The last button, *Delete*, removes a selected component from the list.

The lower group represents all available source attributes (they can be altered by interacting with the source list too).

Point like source structure model component Editor

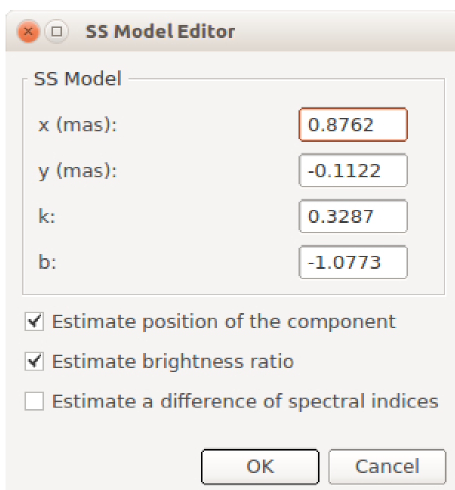
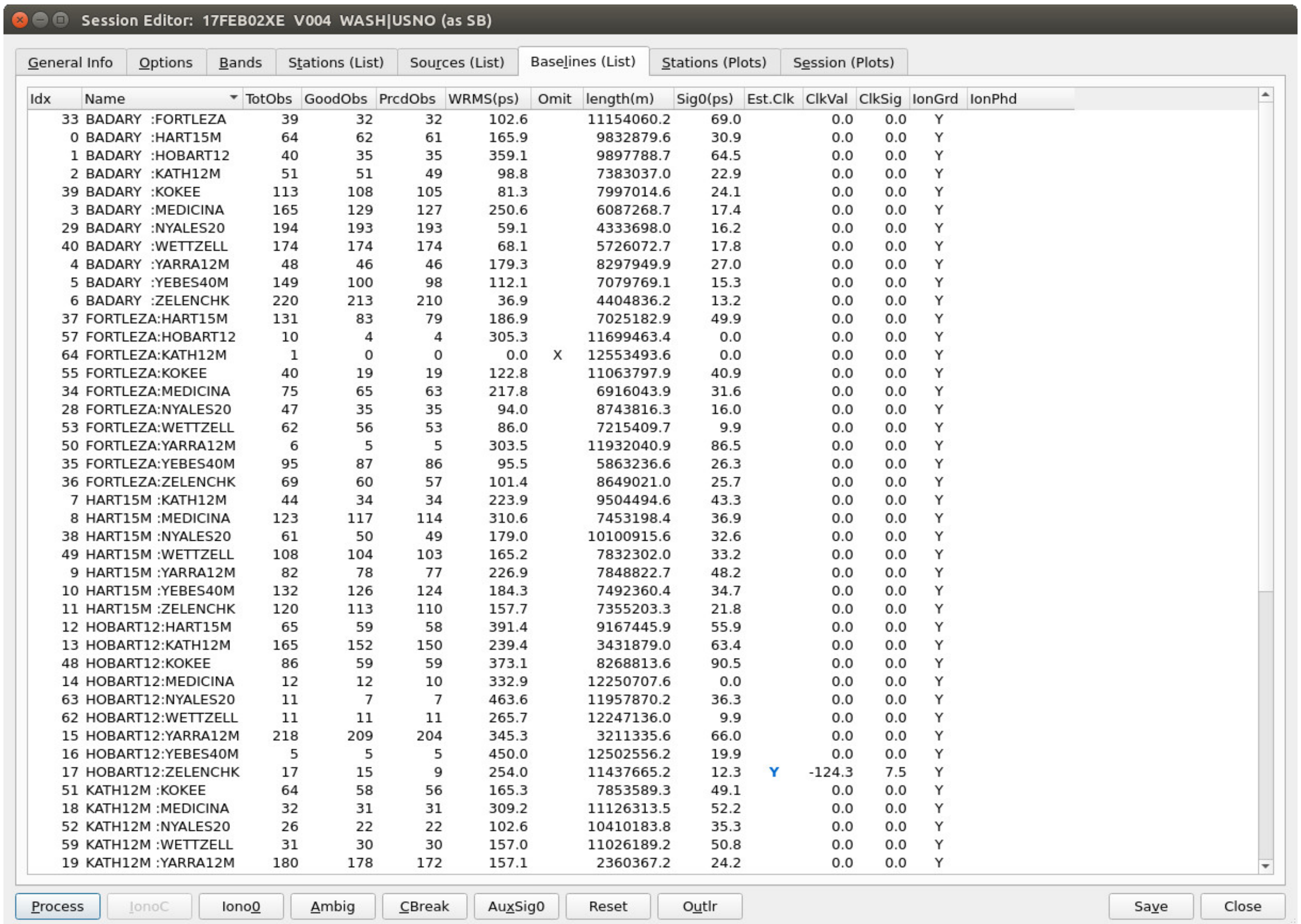


Figure 6.12: Source structure model edit window.

The component editor of the point like source structure model is a simple window that allows a user to provide a relative position of a component (*x(mas)* and *y(mas)* fields), ratio of component brightness with respect to the central component, k, and a difference of spectral indices, b.

A user can specify which parameters of the source structure model should be estimated. The corresponding check boxes are provided for this purpose.

6.2.6 Tab «Baselines (List)»



Idx	Name	TotObs	GoodObs	PrcdObs	WRMS(ps)	Omit	length(m)	Sig0(ps)	Est.Clk	ClkVal	ClkSig	IonGrd	IonPhd
33	BADARY :FORTLEZA	39	32	32	102.6		11154060.2	69.0		0.0	0.0	Y	
0	BADARY :HART15M	64	62	61	165.9		9832879.6	30.9		0.0	0.0	Y	
1	BADARY :HOBART12	40	35	35	359.1		9897788.7	64.5		0.0	0.0	Y	
2	BADARY :KATH12M	51	51	49	98.8		7383037.0	22.9		0.0	0.0	Y	
39	BADARY :KOKEE	113	108	105	81.3		7997014.6	24.1		0.0	0.0	Y	
3	BADARY :MEDICINA	165	129	127	250.6		6087268.7	17.4		0.0	0.0	Y	
29	BADARY :NYALES20	194	193	193	59.1		4333698.0	16.2		0.0	0.0	Y	
40	BADARY :WETTZELL	174	174	174	68.1		5726072.7	17.8		0.0	0.0	Y	
4	BADARY :YARRA12M	48	46	46	179.3		8297949.9	27.0		0.0	0.0	Y	
5	BADARY :YEBES40M	149	100	98	112.1		7079769.1	15.3		0.0	0.0	Y	
6	BADARY :ZELENCHK	220	213	210	36.9		4404836.2	13.2		0.0	0.0	Y	
37	FORTLEZA:HART15M	131	83	79	186.9		7025182.9	49.9		0.0	0.0	Y	
57	FORTLEZA:HOBART12	10	4	4	305.3		11699463.4	0.0		0.0	0.0	Y	
64	FORTLEZA:KATH12M	1	0	0	0.0	X	12553493.6	0.0		0.0	0.0	Y	
55	FORTLEZA:KOKEE	40	19	19	122.8		11063797.9	40.9		0.0	0.0	Y	
34	FORTLEZA:MEDICINA	75	65	63	217.8		6916043.9	31.6		0.0	0.0	Y	
28	FORTLEZA:NYALES20	47	35	35	94.0		8743816.3	16.0		0.0	0.0	Y	
53	FORTLEZA:WETTZELL	62	56	53	86.0		7215409.7	9.9		0.0	0.0	Y	
50	FORTLEZA:YARRA12M	6	5	5	303.5		11932040.9	86.5		0.0	0.0	Y	
35	FORTLEZA:YEBES40M	95	87	86	95.5		5863236.6	26.3		0.0	0.0	Y	
36	FORTLEZA:ZELENCHK	69	60	57	101.4		8649021.0	25.7		0.0	0.0	Y	
7	HART15M :KATH12M	44	34	34	223.9		9504494.6	43.3		0.0	0.0	Y	
8	HART15M :MEDICINA	123	117	114	310.6		7453198.4	36.9		0.0	0.0	Y	
38	HART15M :NYALES20	61	50	49	179.0		10100915.6	32.6		0.0	0.0	Y	
49	HART15M :WETTZELL	108	104	103	165.2		7832302.0	33.2		0.0	0.0	Y	
9	HART15M :YARRA12M	82	78	77	226.9		7848822.7	48.2		0.0	0.0	Y	
10	HART15M :YEBES40M	132	126	124	184.3		7492360.4	34.7		0.0	0.0	Y	
11	HART15M :ZELENCHK	120	113	110	157.7		7355203.3	21.8		0.0	0.0	Y	
12	HOBART12:HART15M	65	59	58	391.4		9167445.9	55.9		0.0	0.0	Y	
13	HOBART12:KATH12M	165	152	150	239.4		3431879.0	63.4		0.0	0.0	Y	
48	HOBART12:KOKEE	86	59	59	373.1		8268813.6	90.5		0.0	0.0	Y	
14	HOBART12:MEDICINA	12	12	10	332.9		12250707.6	0.0		0.0	0.0	Y	
63	HOBART12:NYALES20	11	7	7	463.6		11957870.2	36.3		0.0	0.0	Y	
62	HOBART12:WETTZELL	11	11	11	265.7		12247136.0	9.9		0.0	0.0	Y	
15	HOBART12:YARRA12M	218	209	204	345.3		3211335.6	66.0		0.0	0.0	Y	
16	HOBART12:YEBES40M	5	5	5	450.0		12502556.2	19.9		0.0	0.0	Y	
17	HOBART12:ZELENCHK	17	15	9	254.0		11437665.2	12.3	Y	-124.3	7.5	Y	
51	KATH12M :KOKEE	64	58	56	165.3		7853589.3	49.1		0.0	0.0	Y	
18	KATH12M :MEDICINA	32	31	31	309.2		11126313.5	52.2		0.0	0.0	Y	
52	KATH12M :NYALES20	26	22	22	102.6		10410183.8	35.3		0.0	0.0	Y	
59	KATH12M :WETTZELL	31	30	30	157.0		11026189.2	50.8		0.0	0.0	Y	
19	KATH12M :YARRA12M	180	178	172	157.1		2360367.2	24.2		0.0	0.0	Y	

Figure 6.13: Session Editor window, list of baselines.

The tab *Baselines (List)* displays the attributes of the baselines. As for the previous two tabs, it includes statistical information: the baseline name, total, good and processed numbers of observations, residuals. Also, the column *Omit* allows a user to deselect some particular baseline from the solution. The next two columns display a length of a baseline (meters) and correction of weights (*Sig0(ps)*) for delays.

The column *Est.Clk* marks baselines where clock offsets need to be estimated. Depending on the procedures performed by the correlator, there are cases when a baseline can have a constant clock offset with respect to other baselines (i.e., triangles do not close). To deal with such cases, CALC/SOLVE and νSolve adds an additional parameter, a baseline clock offset. A mouse click in this column turns on the estimation of the offset for the baseline. The character *Y* means «on». By default, when a new VLBI session is read in, this flag is «off» for all baselines. But when a previously processed session is read in (e.g., version 4 of the Mk-3 DBH format), the flags are set according to the baseline clock information stored in the database.

In general, the need for baseline clock offset estimation is relatively rare. At the Goddard we apply the following procedure to the baseline clock offset. First, after all detected anomalies (clock breaks, ambiguities, outliers, etc.) are resolved, then baseline clock offsets are added to the list of the estimated parameters. Then, all baseline clock offsets with values less than three times their standard deviations are removed and the estimation process is repeated. We also do not estimate baseline clock offsets for baselines with a small number of good observations (say, less than 10 points) and for offsets where the estimated values are very small (e.g., less than $10ps$). After reweighting and outlier elimination are performed, we will repeat the check of baseline clock offset values. As a result, baseline clock offsets are usually estimated for only a few baselines.

The columns *ClkVal* and *ClkSig* show offsets and theirs standard deviations (in picoseconds) for baselines which clocks offsets were estimated in the last solution.

To make the process of selection of the baseline clock offsets faster, the symbols *Y* in the column *Est.Clocks* are colored (see Fig. 6.13). The red color means that the absolute value of the estimate is less than its standard deviation. The orange color means that the estimate is greater than one but less than three standard deviations. The black color indicates that the estimated offset is greater than three standard deviations, but less than $10ps$, or was not estimated yet. And the blue color means that the estimation is significant.

The columns *IonGrd* and *IonPhd* represent flags of taking into account ionospheric corrections (if available) for the group and the phase delays. By default, we use the ionosphere corrections for the group delays. If you are not sure, keep it as is.

Baseline Attributes Editor

A double mouse click in the area bounded by columns *Idx* and *Sigma_0* invokes a baseline attributes editor window (see Fig. 6.14). This window allows a user to turn «on» or «off» all available baseline attributes and set a value of additional weight manually for the baseline.

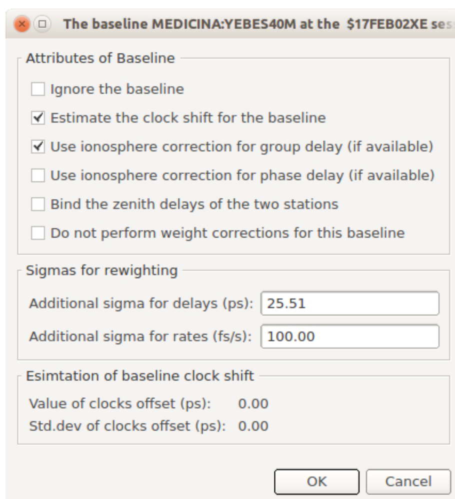


Figure 6.14: Baseline attributes edit window.

The baseline attributes editor window allows to alter the additional sigma for the group delay and delay rates. Also, it displays the estimated baseline clock offset and its standard deviations.

The checkbox *Bind the zenith delays of the two stations* is for tests purposes, do not turn it «on».

If the last check box, *Do not perform weight corrections for this baseline*, is checked on, observations obtained on this baseline will not be used in a procedure of weight corrections to have $chi^2 = 1$. The values of the additional weights, if they are not zeros, will be applied in data analysis.

6.2.7 Tab «Stations (Plots)»

The tab *Stations (Plots)* displays various station dependent data from either measurements or estimations. The Fig. 6.15 shows an example of cable calibrations as a function of time.

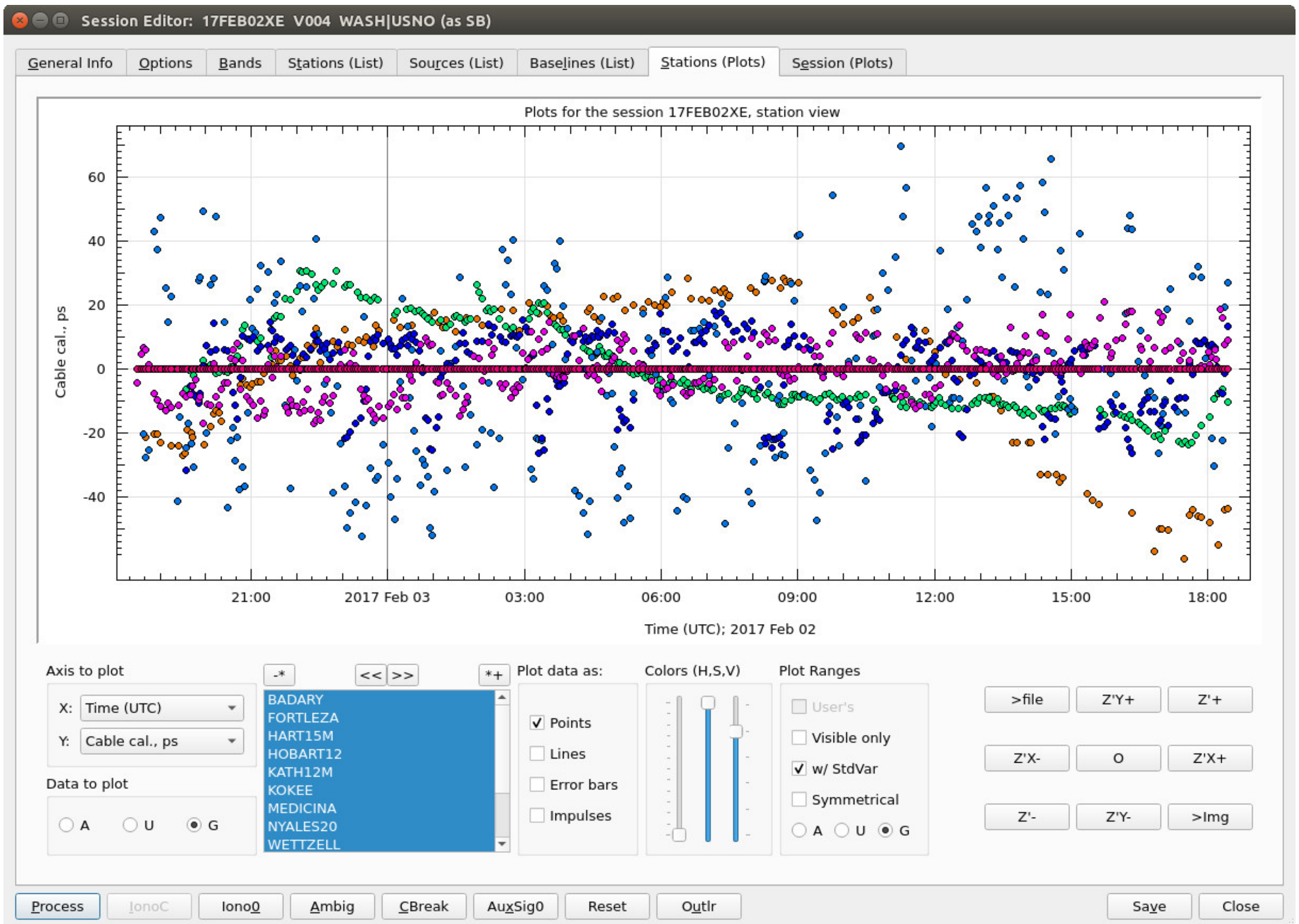
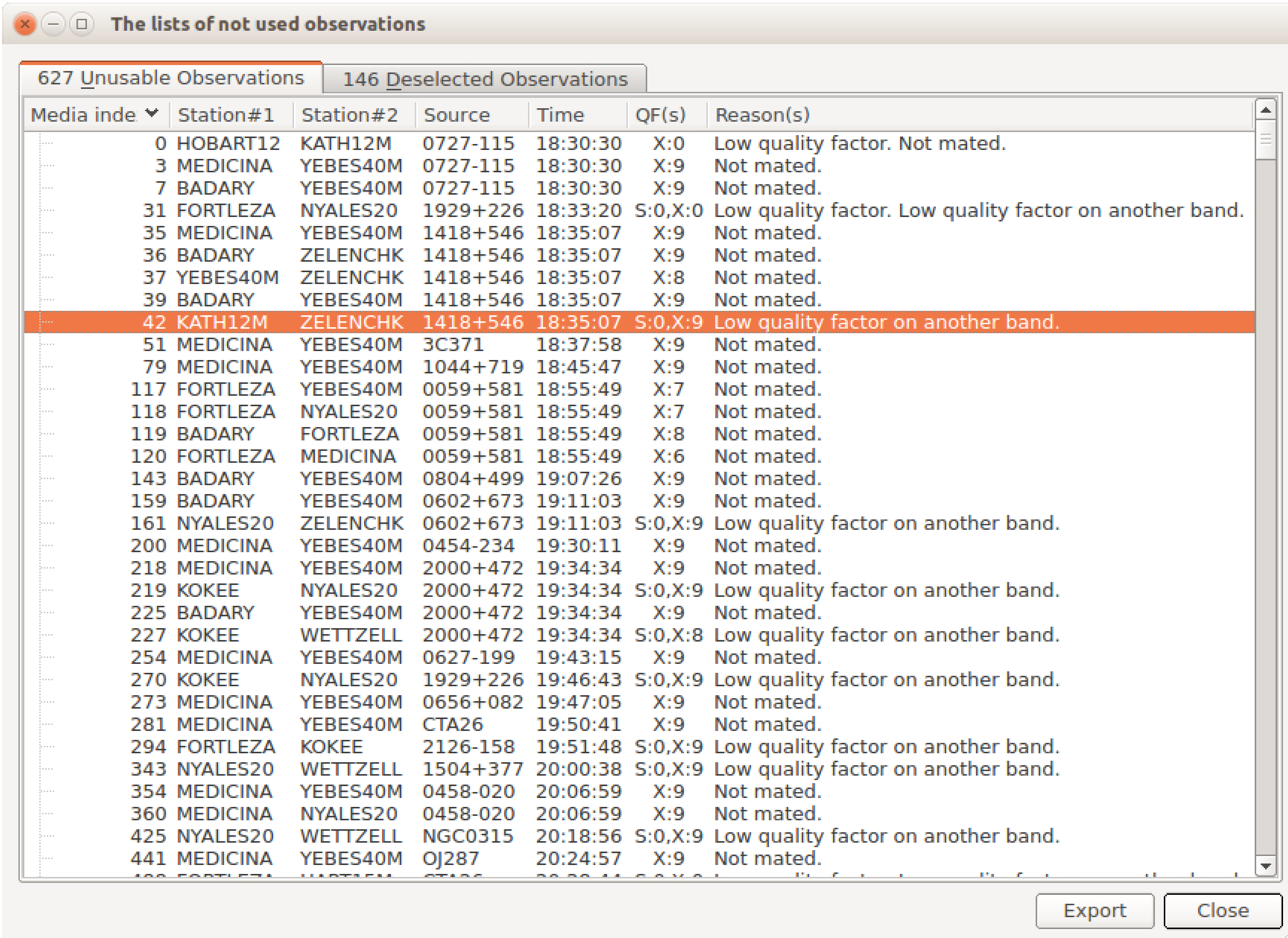


Figure 6.15: Session Editor window, station dependent plots: cable calibration data.

Currently the following measurements are displayed: cable calibration values (if different types of cable calibrations are available, they are plotted as separate data), meteorological parameters (atmospheric temperature, pressure and relative humidity) and antenna pointing (azimuth and elevation, parallactic angle). In addition, the following estimations and their standard deviations are displayed: model of clock function (if time-varying parameters were estimated, e.g., PWL function or stochastic parameters, then polynomial model is not shown), zenith delay and its gradients. Also, a total zenith delay is displayed on this plot.

6.2.8 Not used observation window

The Session Editor window is capable to list observations that are not in a solution. There are two groups of such observations: unusable and deselected observations. The first group are observations that have either quality code that is lower than the threshold or a source, a station or a baseline has been deselected. Also, in some rare cases, when an observation has only one good channel it will be considered as unusable too.



Media inde	Station#1	Station#2	Source	Time	QF(s)	Reason(s)
0	HOBART12	KATH12M	0727-115	18:30:30	X:0	Low quality factor. Not mated.
3	MEDICINA	YEBES40M	0727-115	18:30:30	X:9	Not mated.
7	BADARY	YEBES40M	0727-115	18:30:30	X:9	Not mated.
31	FORTLEZA	NYALES20	1929+226	18:33:20	S:0,X:0	Low quality factor. Low quality factor on another band.
35	MEDICINA	YEBES40M	1418+546	18:35:07	X:9	Not mated.
36	BADARY	ZELENCHK	1418+546	18:35:07	X:9	Not mated.
37	YEBES40M	ZELENCHK	1418+546	18:35:07	X:8	Not mated.
39	BADARY	YEBES40M	1418+546	18:35:07	X:9	Not mated.
42	KATH12M	ZELENCHK	1418+546	18:35:07	S:0,X:9	Low quality factor on another band.
51	MEDICINA	YEBES40M	3C371	18:37:58	X:9	Not mated.
79	MEDICINA	YEBES40M	1044+719	18:45:47	X:9	Not mated.
117	FORTLEZA	YEBES40M	0059+581	18:55:49	X:7	Not mated.
118	FORTLEZA	NYALES20	0059+581	18:55:49	X:7	Not mated.
119	BADARY	FORTLEZA	0059+581	18:55:49	X:8	Not mated.
120	FORTLEZA	MEDICINA	0059+581	18:55:49	X:6	Not mated.
143	BADARY	YEBES40M	0804+499	19:07:26	X:9	Not mated.
159	BADARY	YEBES40M	0602+673	19:11:03	X:9	Not mated.
161	NYALES20	ZELENCHK	0602+673	19:11:03	S:0,X:9	Low quality factor on another band.
200	MEDICINA	YEBES40M	0454-234	19:30:11	X:9	Not mated.
218	MEDICINA	YEBES40M	2000+472	19:34:34	X:9	Not mated.
219	KOKEE	NYALES20	2000+472	19:34:34	S:0,X:9	Low quality factor on another band.
225	BADARY	YEBES40M	2000+472	19:34:34	X:9	Not mated.
227	KOKEE	WETTZELL	2000+472	19:34:34	S:0,X:8	Low quality factor on another band.
254	MEDICINA	YEBES40M	0627-199	19:43:15	X:9	Not mated.
270	KOKEE	NYALES20	1929+226	19:46:43	S:0,X:9	Low quality factor on another band.
273	MEDICINA	YEBES40M	0656+082	19:47:05	X:9	Not mated.
281	MEDICINA	YEBES40M	CTA26	19:50:41	X:9	Not mated.
294	FORTLEZA	KOKEE	2126-158	19:51:48	S:0,X:9	Low quality factor on another band.
343	NYALES20	WETTZELL	1504+377	20:00:38	S:0,X:9	Low quality factor on another band.
354	MEDICINA	YEBES40M	0458-020	20:06:59	X:9	Not mated.
360	MEDICINA	NYALES20	0458-020	20:06:59	X:9	Not mated.
425	NYALES20	WETTZELL	NGC0315	20:18:56	S:0,X:9	Low quality factor on another band.
441	MEDICINA	YEBES40M	OJ287	20:24:57	X:9	Not mated.

Figure 6.16: A list of observations that are not in a solution: unusable observations.

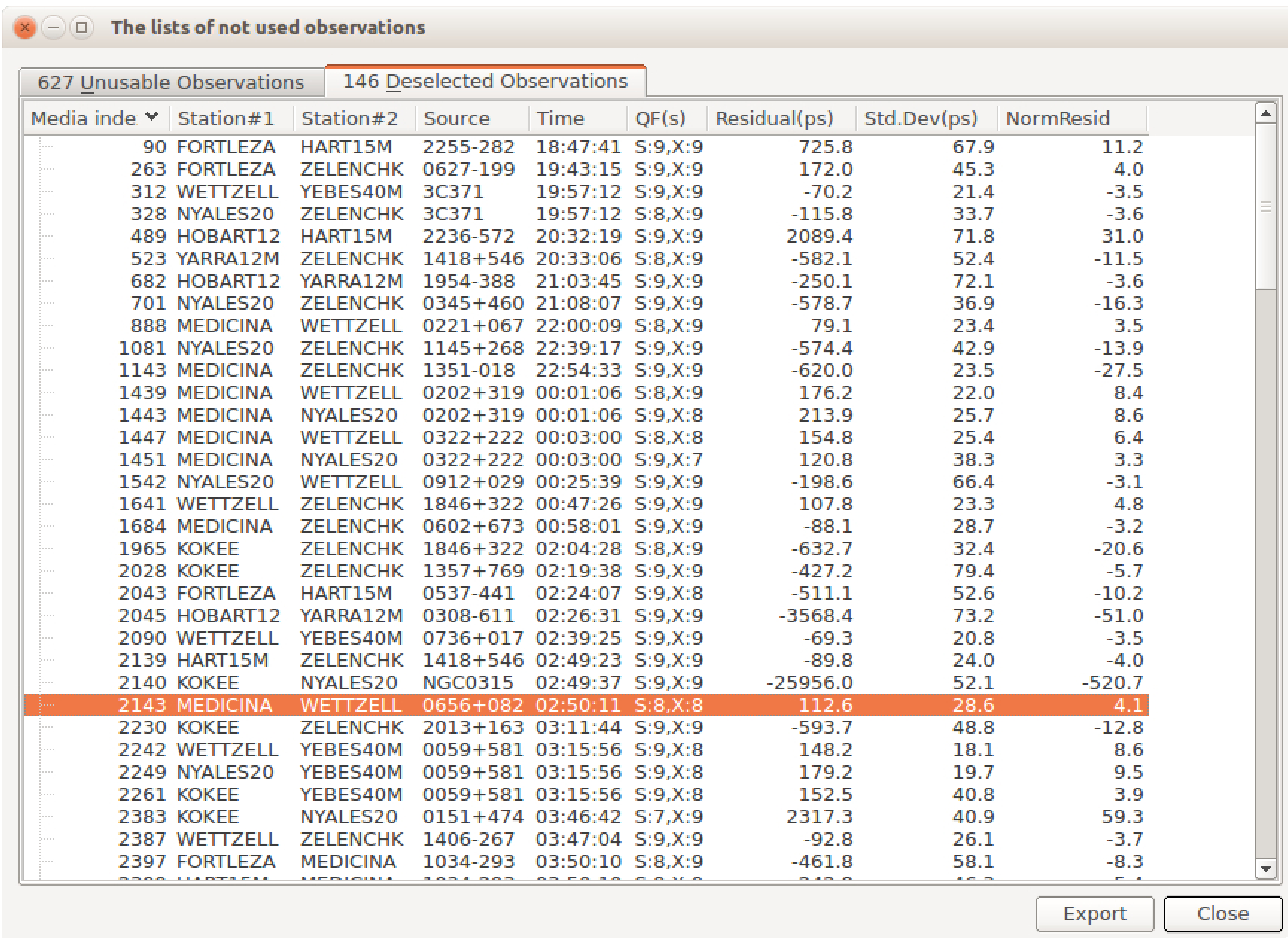
The last group of observations are the observations that were explicitly marked for deselection either by a user or the outlier processing procedure.

At any stage of data analysis a user can press a key combination *Ctrl+i* to invoke *Not used observation* window, see Figs. 6.16–6.17. The window has two tabs, each for each type of not used observations.

The first tab, *Unusable Observations*, displays a list of unusable observations – station and source names, time of observation, quality factors and a reason why the observation cannot be used. The list can be sorted by content of each column with left mouse click on a header of a column.

The second tab, *Deselected Observations*, lists observations that were explicitly removed from a solution. In addition to station and source names and quality factors, the list displays residuals of delays, their standard deviations and the corresponding normalized residual of deselected observation.

The software is capable to save the list of observations with indication of their usability and residuals as an ASCII file. Such file is designed to be used by external utilities, like *anl_comments*, and are generated automatically when a user press *Save* button of the *Session Editor* window. To create the file manually, a user can click the button *Export* of the *Not used observation* window. The file will be written in the directory specified by the field *List of not used observations output* of the software Preferences (see the section 4.1.1).


The lists of not used observations

627 Unusable Observations | 146 Deselected Observations

Media inde	Station#1	Station#2	Source	Time	QF(s)	Residual(ps)	Std.Dev(ps)	NormResid
90	FORTLEZA	HART15M	2255-282	18:47:41	S:9,X:9	725.8	67.9	11.2
263	FORTLEZA	ZELENCHK	0627-199	19:43:15	S:9,X:9	172.0	45.3	4.0
312	WETTZELL	YEBES40M	3C371	19:57:12	S:9,X:9	-70.2	21.4	-3.5
328	NYALES20	ZELENCHK	3C371	19:57:12	S:8,X:9	-115.8	33.7	-3.6
489	HOBART12	HART15M	2236-572	20:32:19	S:9,X:9	2089.4	71.8	31.0
523	YARRA12M	ZELENCHK	1418+546	20:33:06	S:8,X:9	-582.1	52.4	-11.5
682	HOBART12	YARRA12M	1954-388	21:03:45	S:9,X:9	-250.1	72.1	-3.6
701	NYALES20	ZELENCHK	0345+460	21:08:07	S:9,X:9	-578.7	36.9	-16.3
888	MEDICINA	WETTZELL	0221+067	22:00:09	S:8,X:9	79.1	23.4	3.5
1081	NYALES20	ZELENCHK	1145+268	22:39:17	S:9,X:9	-574.4	42.9	-13.9
1143	MEDICINA	ZELENCHK	1351-018	22:54:33	S:9,X:9	-620.0	23.5	-27.5
1439	MEDICINA	WETTZELL	0202+319	00:01:06	S:8,X:9	176.2	22.0	8.4
1443	MEDICINA	NYALES20	0202+319	00:01:06	S:9,X:8	213.9	25.7	8.6
1447	MEDICINA	WETTZELL	0322+222	00:03:00	S:8,X:8	154.8	25.4	6.4
1451	MEDICINA	NYALES20	0322+222	00:03:00	S:9,X:7	120.8	38.3	3.3
1542	NYALES20	WETTZELL	0912+029	00:25:39	S:9,X:9	-198.6	66.4	-3.1
1641	WETTZELL	ZELENCHK	1846+322	00:47:26	S:9,X:9	107.8	23.3	4.8
1684	MEDICINA	ZELENCHK	0602+673	00:58:01	S:9,X:9	-88.1	28.7	-3.2
1965	KOKEE	ZELENCHK	1846+322	02:04:28	S:8,X:9	-632.7	32.4	-20.6
2028	KOKEE	ZELENCHK	1357+769	02:19:38	S:9,X:9	-427.2	79.4	-5.7
2043	FORTLEZA	HART15M	0537-441	02:24:07	S:9,X:8	-511.1	52.6	-10.2
2045	HOBART12	YARRA12M	0308-611	02:26:31	S:9,X:9	-3568.4	73.2	-51.0
2090	WETTZELL	YEBES40M	0736+017	02:39:25	S:9,X:9	-69.3	20.8	-3.5
2139	HART15M	ZELENCHK	1418+546	02:49:23	S:9,X:9	-89.8	24.0	-4.0
2140	KOKEE	NYALES20	NGC0315	02:49:37	S:9,X:9	-25956.0	52.1	-520.7
2143	MEDICINA	WETTZELL	0656+082	02:50:11	S:8,X:8	112.6	28.6	4.1
2230	KOKEE	ZELENCHK	2013+163	03:11:44	S:9,X:9	-593.7	48.8	-12.8
2242	WETTZELL	YEBES40M	0059+581	03:15:56	S:9,X:8	148.2	18.1	8.6
2249	NYALES20	YEBES40M	0059+581	03:15:56	S:9,X:8	179.2	19.7	9.5
2261	KOKEE	YEBES40M	0059+581	03:15:56	S:9,X:8	152.5	40.8	3.9
2383	KOKEE	NYALES20	0151+474	03:46:42	S:7,X:9	2317.3	40.9	59.3
2387	WETTZELL	ZELENCHK	1406-267	03:47:04	S:9,X:9	-92.8	26.1	-3.7
2397	FORTLEZA	MEDICINA	1034-293	03:50:10	S:8,X:9	-461.8	58.1	-8.3

Export Close

Figure 6.17: A list of observations that are not in a solution: deselected by a user observations.

Chapter 7

Selected practical issues of using νSolve in a GUI mode

7.1 Processing a regular VLBI session

In this section we overview the operations necessary to analyze a regular 24-hour VLBI session. In general, we start with simple parameterization, only clock shifts and rates, and perform an analysis of the single band delays. At this stage we check for possible clock breaks at stations. Then, we process to the group delays to resolve 2π ambiguities and, again, possible effects that look like clock breaks. Before ambiguities and clock breaks are resolved, there is no sense in estimating other parameters except the polynomials of the clock functions.

When these two phenomena, clock breaks and unresolved ambiguities are fixed, we add zenith delays and station positions to the list of estimated parameters and check for outliers. Also, we calculate ionospheric corrections.

Time-varying models of clock and tropospheric parameters are introduced in the last stage. Also, other parameters are added: the rate of Earth rotation, angles of nutation, and baselines clock offsets. At this stage we also do a reweighting of the observations and process the outliers. The last two operations are performed in conjunction.

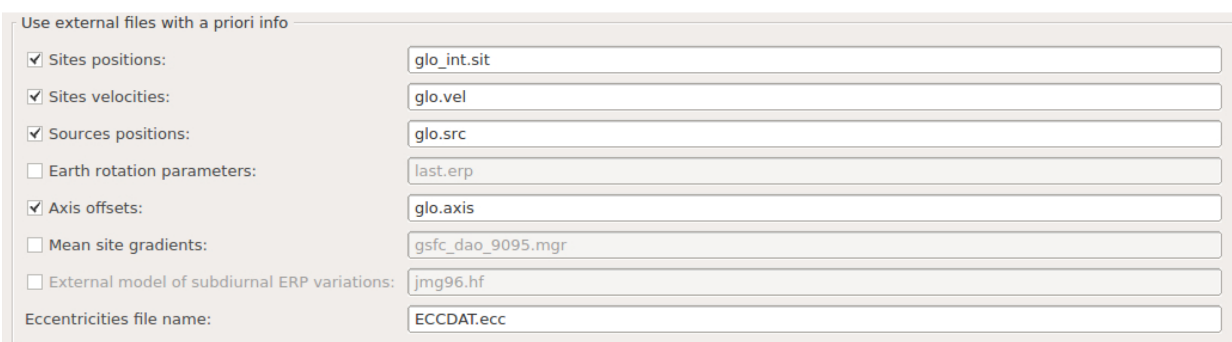


Figure 7.1: GUI: use of external *a priori* files.

Before you make any analysis, verify that you have all the necessary files with *a priori* data. Check the tab *Options*, the subtab *External a priori and models*, Fig. 7.1. If you do not have the files, turn the corresponding checkboxes «off». Some of the files can be obtained from

$$https://cddis.nasa.gov/archive/vlbi/gsfc/ancillary/solve\_apriori/$$

It is recommended to use the *a priori* files at least for station positions, station velocities and source coordinates. Also, keep information in these files updated, it will save you time.

7.1.1 Reading the session and preparing for processing

For a demonstration of data analysis we use IVS-R4 session 13SEP05XE. This is a regular VLBI session, it has one clock break effect at SVETLOE in the S-band and mixed value of ambiguity spacings in the S-band. The clock break effect is caused by applied manual phase calibration in two parts.

First, the user has to read the session into νSolve. If the session is in the database format, two files (S- and X-band) are expected.

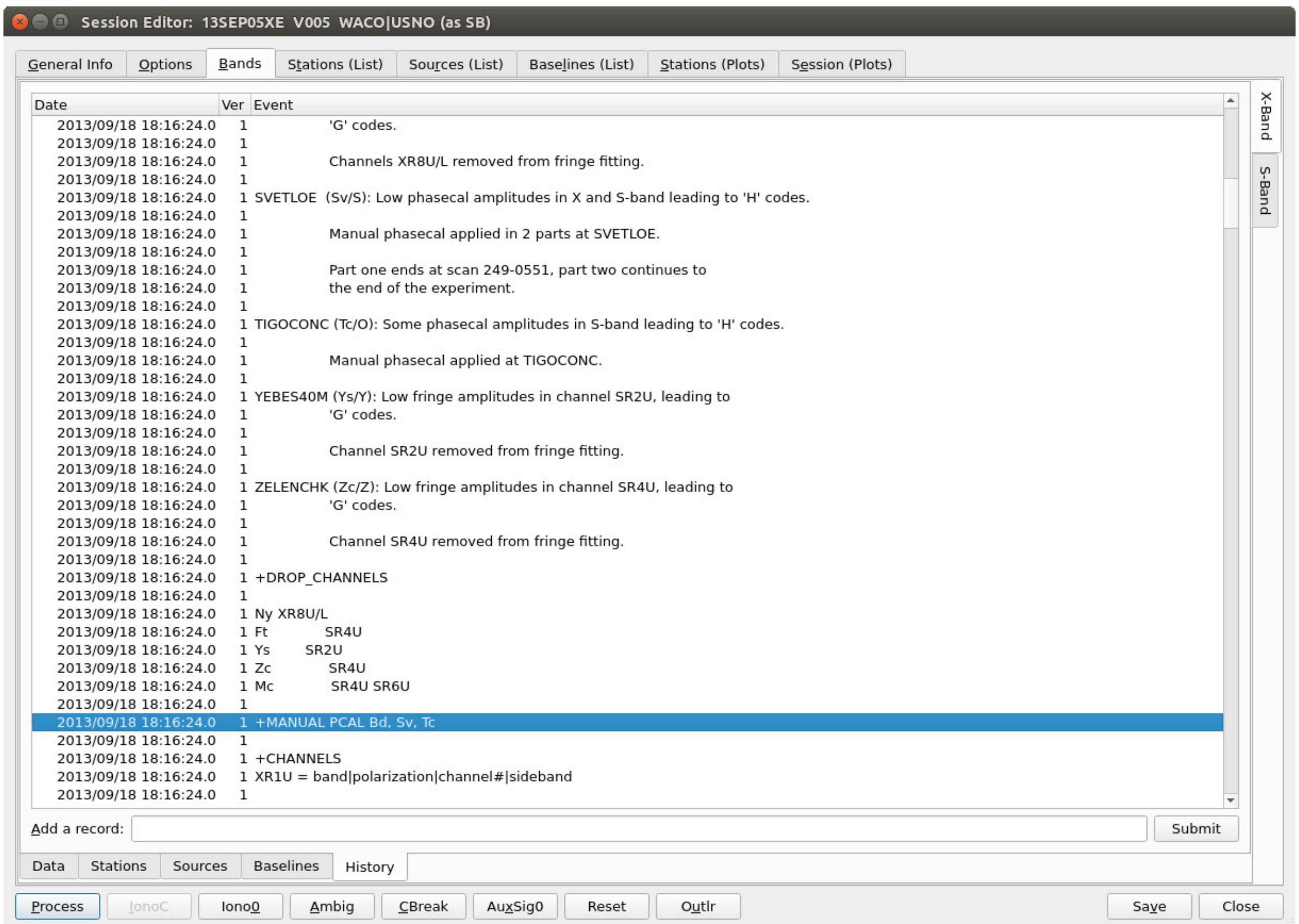


Figure 7.2: The session 13SEP05XE: the history records.

After the files are imported and the Session Edit window has appeared on the screen, check the history part of the session (preferable the X-band), see Fig. 7.2. To do so, select the *Bands* tab of the Session Editor and then select the *History* tab of the X-band.

The highlighted text on the figure history record says:

```
+MANUAL PCAL Bd, Sv, Tc
```

It is a part of the correlator report and means that manual phase calibration was applied for BADARY, SVETLOE and TIGOCONC. Also, the correlator comments on station performance are in a section above this record.

Normally if the correlator applied manual phase calibration, we should not use the cable calibration data. On the tab *Stations (List)*, Fig. 7.3, we deselect the use of cable calibration data for these stations. Also, KOKEE is known to have incorrect cable calibration measurements, so for this station use of the cable calibration data is turned off too.

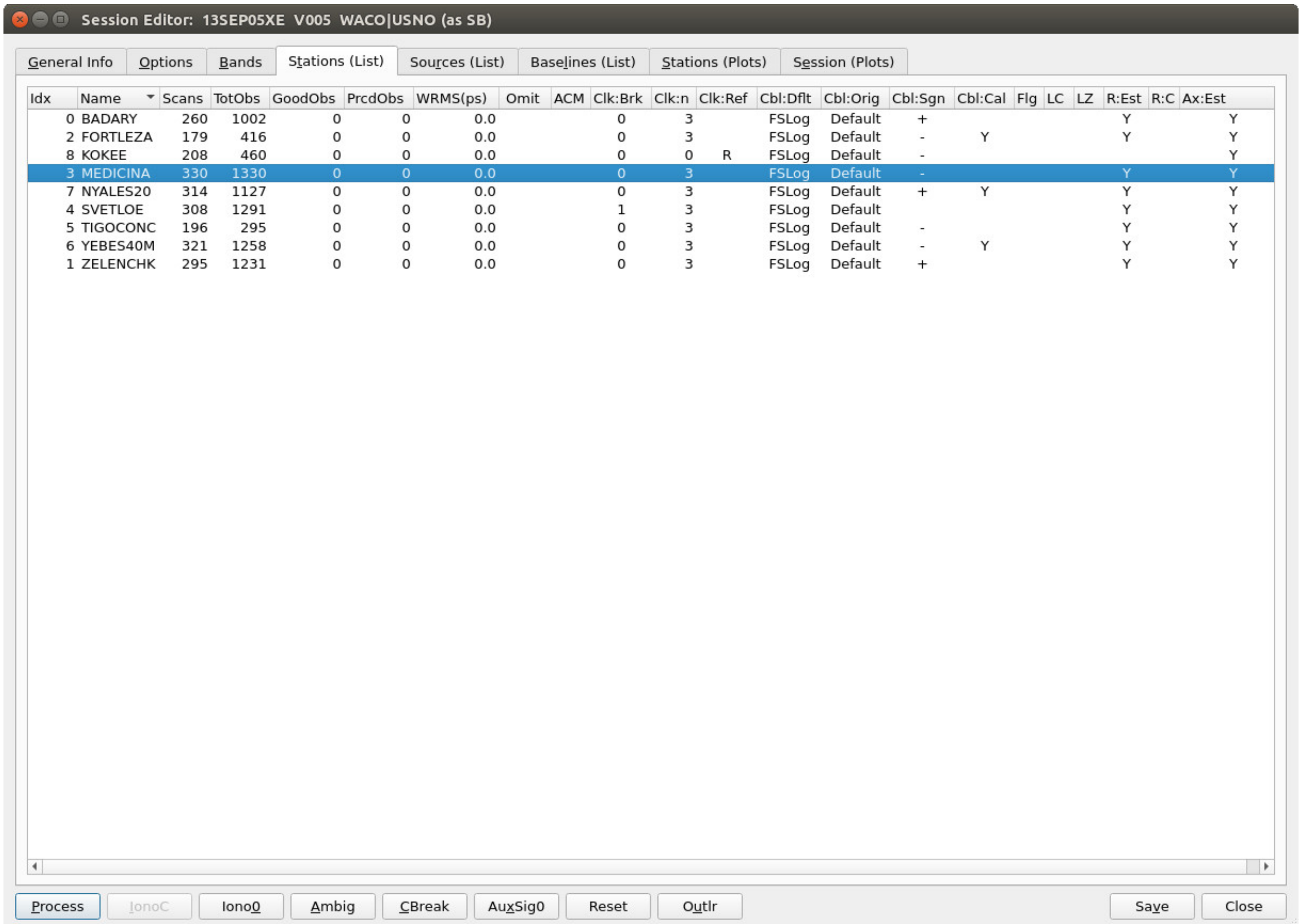


Figure 7.3: The session 13SEP05XE: attributes of the stations.

If the checkbox *Perform set up of the session* of the configuration tab *Post import actions* is «on» for a network of the session (see subsection 4.2.4), νSolve will check the history records and will turn off the cable calibrations automatically for these stations (in this case you can see a note in the log, as it shown on Fig. 7.4). Since there is no fixed format of reporting use of manual phase calibrations and correlator reports are written by humans, the procedure of analysis of history records can misinterpret the records and assign a wrong flag for a wrong station. We would suggest to check history records manually even if the procedure of session setup is scheduled after the data were read.

We chose KOKEE as the reference clock station. We set the number of its polynomial terms to zero (in this case the clock parameters will not be estimated at all) and set the flag *Clk:Ref* (a station with this flag will be

```
13:35:15 SgVlbiSession::setReferenceClocksStation(): set a station KOKEE    as a reference clocks station
13:35:15 SgVlbiSession::setReferenceCoordinatesStation(): set a station KOKEE    as a reference coordinate station
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): found manual phasecal record for BADARY   in the station block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): found manual phasecal record for SVETLOE  in the station block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): found manual phasecal record for TIGOCONC in the station block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): the use of manual phasecal was mention for the station BADARY  (Bd) in the manual phasecal block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): the use of manual phasecal was mention for the station SVETLOE (Sv) in the manual phasecal block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): the use of manual phasecal was mention for the station TIGOCONC(Tc) in the manual phasecal block
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): cable calibrations for station BADARY   have been turned off because of applied manual phase calibrations
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): cable calibrations for station SVETLOE  have been turned off because of applied manual phase calibrations
13:35:15 SgVlbiSession::checkUseOfManualPhaseCals(): cable calibrations for station TIGOCONC have been turned off because of applied manual phase calibrations
```

Figure 7.4: The session 13SEP05XE: part of the log, νSolve detected manual phase calibration for BADARY, SVETLOE and TIGOCONC and turned off the use of cable calibrations for these stations.

declared a «reference clock station» in the output, database or vgosDb format; also, if the number of polynomial model is not set to zero, a constraints will be applied to the clock parameters of the station) for the station, see Fig. 7.3. Also, for station NYALES20 the flag "Estimate position" is not set, we consider it to be the reference station.

Before processing the session, check the data collected at the stations, *Stations (Plots)* tab of the Session Editor. For this session there is a break in the cable calibration data for MEDICINA, see Fig. 7.5.

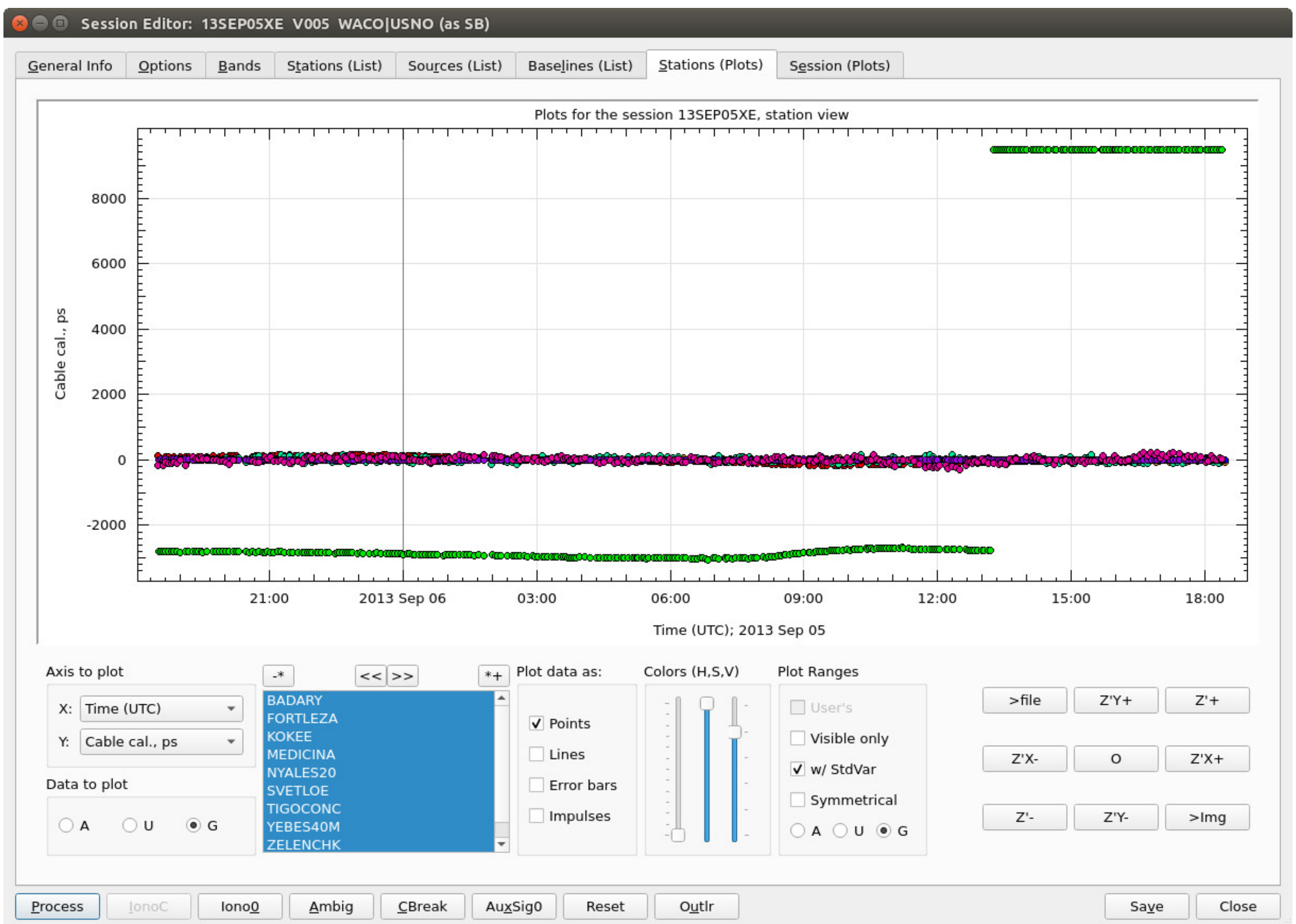


Figure 7.5: Session 13SEP05XE: cable calibrations data.

Such effects are relatively rare and, sometimes reflect actual cable behavior. To figure out is this is a real change in cables or some artificial effect, we need to make an analysis of the session and check for residuals of station MEDICINA. If there is a clock break of about 12ns when the MEDICINA cable calibrations are applied, then we would need to tun off the cable calibration data for this station.

7.1.2 Processing single band delay

To obtain a solution, press the *Process* button at the bottom of the Session editor. By default, we begin data analysis using the single band delays. If the user did not switch to another type of observables, a single band delay solution will be obtained using a simple model – only clock offsets and rates will be estimated. To see the results of this solution switch to residuals, the tab *Bands*, subtab *Data*, see Fig. 7.6.

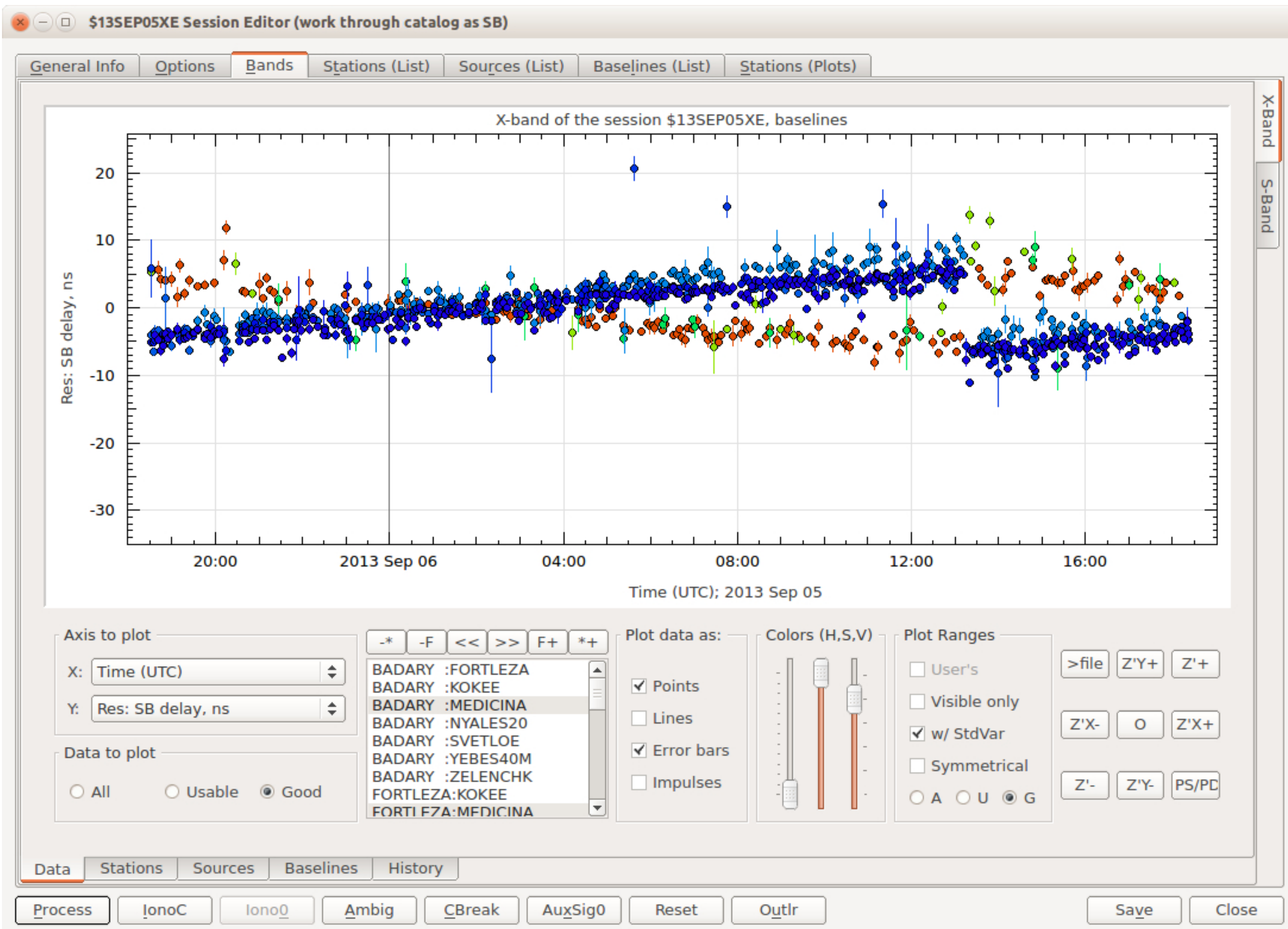


Figure 7.6: Session 13SEP05XE: single band delay residuals.

On these plots only the residuals for MEDICINA are displayed. As one can see, there is an expected clock break, so we need to turn off the use of cable calibration for MEDICINA. Switch to *Stations (List)* and turn off the proper flag. Repeating the estimation of clocks shows that there is no longer a visible clock break for MEDICINA after the cable calibration is turned off.

Since the single band delay residuals do not reveal any other clock break effects, we can switch to the group delays and continue the analysis. At the *Band* tab of the window, select the *Data* tab, then click on the combobox of the *Y* axis in the *Axis to Plot* group of the plotter. Select the *Res: GR delay, ns* option to plot the group delay residuals (see Fig. 7.7).

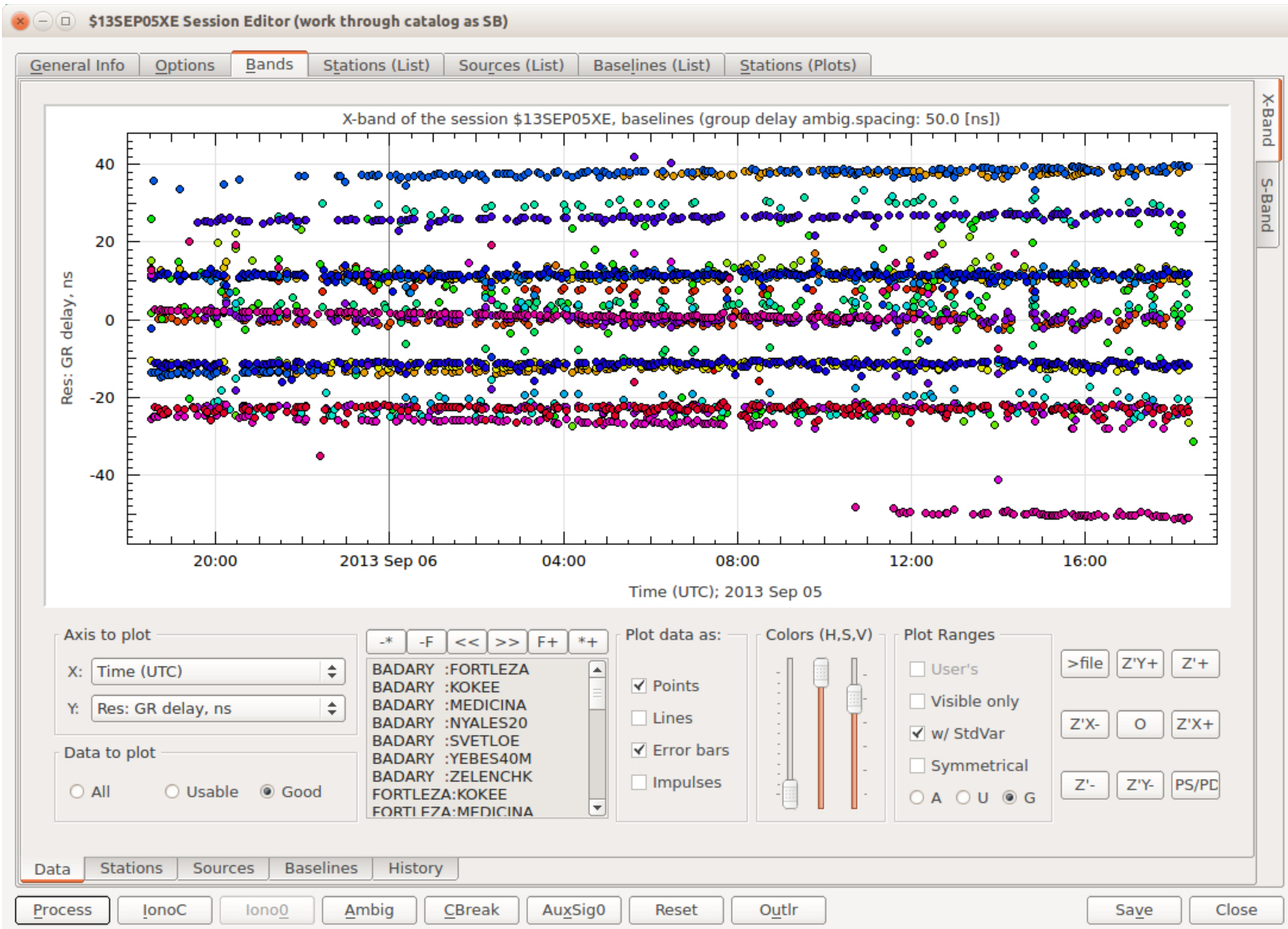


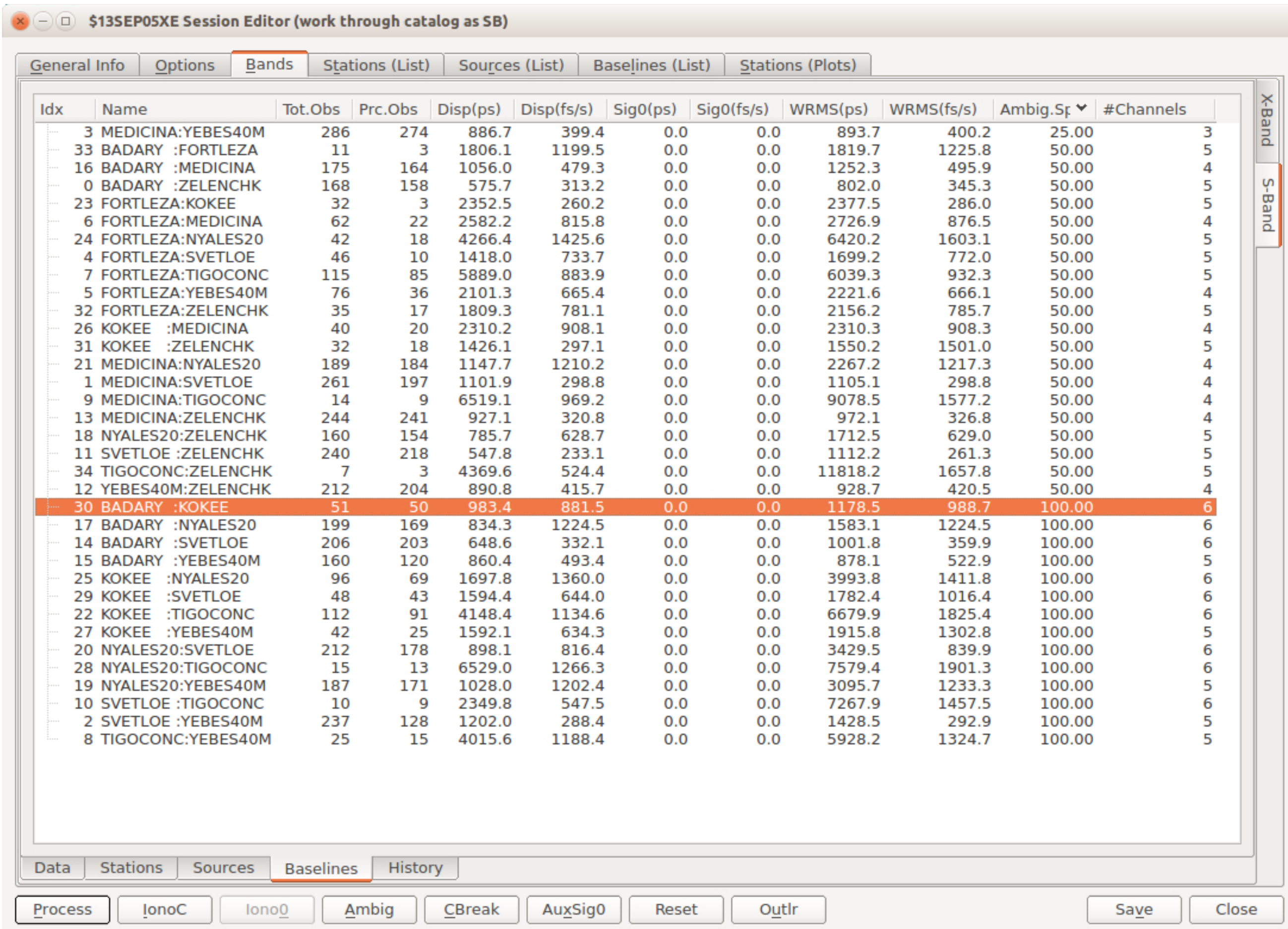
Figure 7.7: Session 13SEP05XE: group delay residuals.

On the plot one can see the group delay residuals calculated using a solution for the single band delays. Differences from these two observables are caused by contribution from the ionosphere and unresolved ambiguities. If you add lines to the plots (checkbox *Lines* in the group *Plot data as* of the plotter) or display each baseline one by one, you can see the effect of the unresolved ambiguities.

7.1.3 Resolving ambiguities

νSolve has two modes for fixing the ambiguities – manual and automatic. In the manual mode, a user marks one or more points and presses either the "-" key or the "=" key to adjust ambiguity multipliers. To invoke the automatic mode, press the *Ambig* button of the Session Editor window. Usually, the automatic mode should be used to resolve the ambiguities, and adjustments should be made using the manual mode when it is necessary.

The group delay ambiguities have to be resolved for each band separately and before including the ionosphere corrections for the group delays.



Idx	Name	Tot.Obs	Prc.Obs	Disp(ps)	Disp(fs/s)	Sig0(ps)	Sig0(fs/s)	WRMS(ps)	WRMS(fs/s)	Ambig.Sp	#Channels
3	MEDICINA:YEBES40M	286	274	886.7	399.4	0.0	0.0	893.7	400.2	25.00	3
33	BADARY :FORTLEZA	11	3	1806.1	1199.5	0.0	0.0	1819.7	1225.8	50.00	5
16	BADARY :MEDICINA	175	164	1056.0	479.3	0.0	0.0	1252.3	495.9	50.00	4
0	BADARY :ZELENCHK	168	158	575.7	313.2	0.0	0.0	802.0	345.3	50.00	5
23	FORTLEZA:KOKEE	32	3	2352.5	260.2	0.0	0.0	2377.5	286.0	50.00	5
6	FORTLEZA:MEDICINA	62	22	2582.2	815.8	0.0	0.0	2726.9	876.5	50.00	4
24	FORTLEZA:NYALES20	42	18	4266.4	1425.6	0.0	0.0	6420.2	1603.1	50.00	5
4	FORTLEZA:SVETLOE	46	10	1418.0	733.7	0.0	0.0	1699.2	772.0	50.00	5
7	FORTLEZA:TIGOCONC	115	85	5889.0	883.9	0.0	0.0	6039.3	932.3	50.00	5
5	FORTLEZA:YEBES40M	76	36	2101.3	665.4	0.0	0.0	2221.6	666.1	50.00	4
32	FORTLEZA:ZELENCHK	35	17	1809.3	781.1	0.0	0.0	2156.2	785.7	50.00	5
26	KOKEE :MEDICINA	40	20	2310.2	908.1	0.0	0.0	2310.3	908.3	50.00	4
31	KOKEE :ZELENCHK	32	18	1426.1	297.1	0.0	0.0	1550.2	1501.0	50.00	5
21	MEDICINA:NYALES20	189	184	1147.7	1210.2	0.0	0.0	2267.2	1217.3	50.00	4
1	MEDICINA:SVETLOE	261	197	1101.9	298.8	0.0	0.0	1105.1	298.8	50.00	4
9	MEDICINA:TIGOCONC	14	9	6519.1	969.2	0.0	0.0	9078.5	1577.2	50.00	4
13	MEDICINA:ZELENCHK	244	241	927.1	320.8	0.0	0.0	972.1	326.8	50.00	4
18	NYALES20:ZELENCHK	160	154	785.7	628.7	0.0	0.0	1712.5	629.0	50.00	5
11	SVETLOE :ZELENCHK	240	218	547.8	233.1	0.0	0.0	1112.2	261.3	50.00	5
34	TIGOCONC:ZELENCHK	7	3	4369.6	524.4	0.0	0.0	11818.2	1657.8	50.00	5
12	YEBES40M:ZELENCHK	212	204	890.8	415.7	0.0	0.0	928.7	420.5	50.00	4
30	BADARY :KOKEE	51	50	983.4	881.5	0.0	0.0	1178.5	988.7	100.00	6
17	BADARY :NYALES20	199	169	834.3	1224.5	0.0	0.0	1583.1	1224.5	100.00	6
14	BADARY :SVETLOE	206	203	648.6	332.1	0.0	0.0	1001.8	359.9	100.00	6
15	BADARY :YEBES40M	160	120	860.4	493.4	0.0	0.0	878.1	522.9	100.00	5
25	KOKEE :NYALES20	96	69	1697.8	1360.0	0.0	0.0	3993.8	1411.8	100.00	6
29	KOKEE :SVETLOE	48	43	1594.4	644.0	0.0	0.0	1782.4	1016.4	100.00	6
22	KOKEE :TIGOCONC	112	91	4148.4	1134.6	0.0	0.0	6679.9	1825.4	100.00	6
27	KOKEE :YEBES40M	42	25	1592.1	634.3	0.0	0.0	1915.8	1302.8	100.00	5
20	NYALES20:SVETLOE	212	178	898.1	816.4	0.0	0.0	3429.5	839.9	100.00	6
28	NYALES20:TIGOCONC	15	13	6529.0	1266.3	0.0	0.0	7579.4	1901.3	100.00	6
19	NYALES20:YEBES40M	187	171	1028.0	1202.4	0.0	0.0	3095.7	1233.3	100.00	5
10	SVETLOE :TIGOCONC	10	9	2349.8	547.5	0.0	0.0	7267.9	1457.5	100.00	6
2	SVETLOE :YEBES40M	237	128	1202.0	288.4	0.0	0.0	1428.5	292.9	100.00	5
8	TIGOCONC:YEBES40M	25	15	4015.6	1188.4	0.0	0.0	5928.2	1324.7	100.00	5

Figure 7.8: Session 13SEP05XE: Ambiguity spacings on the S-band.

So, press the button to resolve the ambiguities. Then make a new solution. The residuals for the X-band will be in the range of 20ns, which is smaller than the ambiguity spacing. After that, switch to the S-band (select the tab *S-Band* in the top right part of the window) and repeat the procedure. For the S-band, the scatter is usually much bigger. Also, it often happens that, due to lost channels at one or more stations, the ambiguity spacing can vary depending on the stations that form a baseline. The typical value of the ambiguity spacings for each baseline is showed on *Baselines* tab in the bottom of the tab *Bands*.

A left mouse button click on the header *Ambig.Spc* of the *Baselines* tab sorts the column in numerical order, Fig 7.8. For our session the baseline MEDICINA:YEBES40M has ambiguity spacing equal to 25ns, all other baselines with MEDICINA as well as the baselines with FORTLEZA and ZELENCHK have ambiguity spacings of 50ns, and all remaining baselines have ambiguity spacings of 100ns.

The combination of large scatter and small ambiguity spacing makes it hard to resolve the ambiguities in automatic mode. You will need to repeat the operation several times. If necessary, roll back to the single band delay solution and repeat the operation or adjust ambiguities manually.

The following algorithm could help in complicated cases: turn off stations with clock breaks; deselect all baselines but one of stations which ambiguity spacings less than the nominal value (usually, keep selected a baseline with the reference clock station). Resolve ambiguities. Manually adjust ambiguities for deselected baselines – on the plot press -* button, than highlight only one particular baseline, turn on plotting all or usable observations (the radio button *A* or *U* in the *Plot Ranges* widget group). and adjust the ambiguities manually for all observations of the baseline. If everything is ok, turn on the stations with clock breaks and resolve ambiguities for these stations. It should be noted also, if a station is deselected, all its baselines will be deselected too by the software. The software deselects a station if all its baselines are deselected too. So, if you turn on a station (on the *Stations (List)* tab) you have to turn on its baselines also (on the *Baselines (List)* tab).

As one can see, the station SVETLOE has a clock break effect at S-band. The reason for this break in the residuals is a manually applied phase calibration that consists of two parts. There are records in the correlator report (see the history part):

```
SVETLOE  (Sv/S): Low phasecal amplitudes in X and S-band leading to 'H' codes.

    Manual phasecal applied in 2 parts at SVETLOE.

    Part one ends at scan 249-0551, part two continues to
    the end of the experiment.
```

After all ambiguities are resolved, the residuals should look like the ones shown in Fig. 7.9. The clock break at SVETLOE is clearly visible.

7.1.4 Processing a clock break

In the software there are two approaches to take into account a clock break. The first one is to estimate clock break magnitudes in a solution (as interactive SOLVE does). The second approach is to add a stepwise linear function to compensate for the break. Both approaches have their own pluses and minuses. For the first type of clock breaks we do not need to know a magnitude of the break, on the other hand, if a time interval between two breaks is short, global SOLVE will fail to obtain a solution due to high correlations.

The user can add a clock break to observations on one particular band or to all data. Clock breaks that are set up for a band can be only of one type, a stepwise linear function. Clock breaks that are applied to all observations could be of both types. When the software adds a clock break and the check box *Estimate clock break parameters in common solution* on the sub-tab *Options –> General* is «on» (see section 4.2.1), then the clock break will be added to whole session and will be of the second type.

The description of the clock break event consists of the station name, the epoch of the break, and the magnitude (for the first type of clock breaks) of the break. There are three options for processing a clock break. With the first option, manual, the user specifies the parameters of the break explicitly in a special window (see Fig. 6.9). With the second option, semiautomatic, the user provides to νSolve the station name and the epoch of the break, and νSolve evaluates the magnitude of the break. This option will be discussed in detail later. With the last option, automatic, the software searches for a clock break and evaluates parameters by itself. To invoke this procedure, press the *CBreak* button in the bottom of the Session Editor window. It should work fine for this session (with proper *a priori* files and correctly resolved ambiguities), but the procedure for clock break detection currently is in the embryonic stage, and there are cases where it will not work.

Here we will describe how to deal with clock breaks in semiautomatic mode. If you already pressed the *CBreak* button and the break has vanished, just delete the clock break record. To do it, follow the instructions:

- if the option *Estimate clock break parameters in common solution* is turned «off», in the tab *Bands* select sub-tab *Stations* (at the bottom of the tab). Otherwise, select the tab *Stations (List)*;
- double click on the station SVETLOE – a station parameter editor will appear;
- highlight the clock break entry in the *List of Clock Break Events* and press the *Delete* button;
- answer with the *Yes* button on the prompt about deletion;

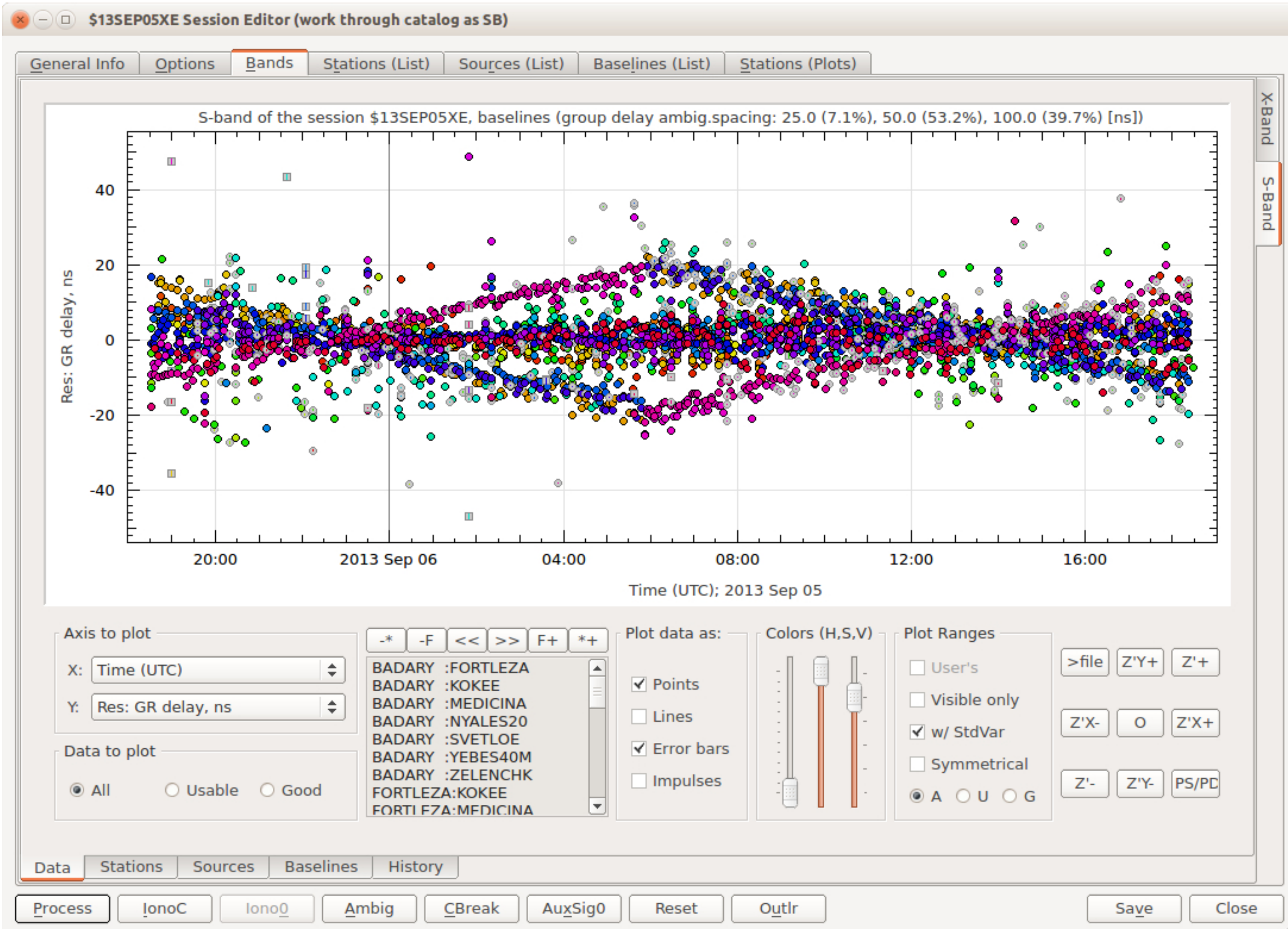


Figure 7.9: Session 13SEP05XE: group delay residuals on the S-band. A clock break effect is on baselines of SVETLOE.

– close the window with the *Ok* button;

– return back to the *Data* sub-tab;

– press the *Process* button to recalculate the residuals.

As a result, you should get the same distribution of residuals as before in Fig. 7.9. To process a clock break in semiautomatic mode, we need to highlight the rightmost points before the break in the few baselines where the break has occurred. Here is a step-by-step instruction of how to do it. First, press the -* button above the list of baselines of the plot to unselect all the data. Then, click with mouse right button on the button *F+* above the baseline list and select from the menu the entry *SVETLOE:*. The plotter will select only those baselines in which SVETLOE is the first station. Mark the points before the clock break by pressing the left mouse button and drag the marking area to include the points (see Fig. 5.5). At the end, you should get a plot such as the one shown in the top part of Fig. 7.10.

Unselect all baselines by pressing the -* button, and click mouse right button on the button *F+* again. This time, choose the entry *:SVETLOE* to select the baselines in which SVETLOE is the second station. Again, mark the rightmost points before the break. You should get a plot such as the one shown in the middle part of Fig. 7.10.

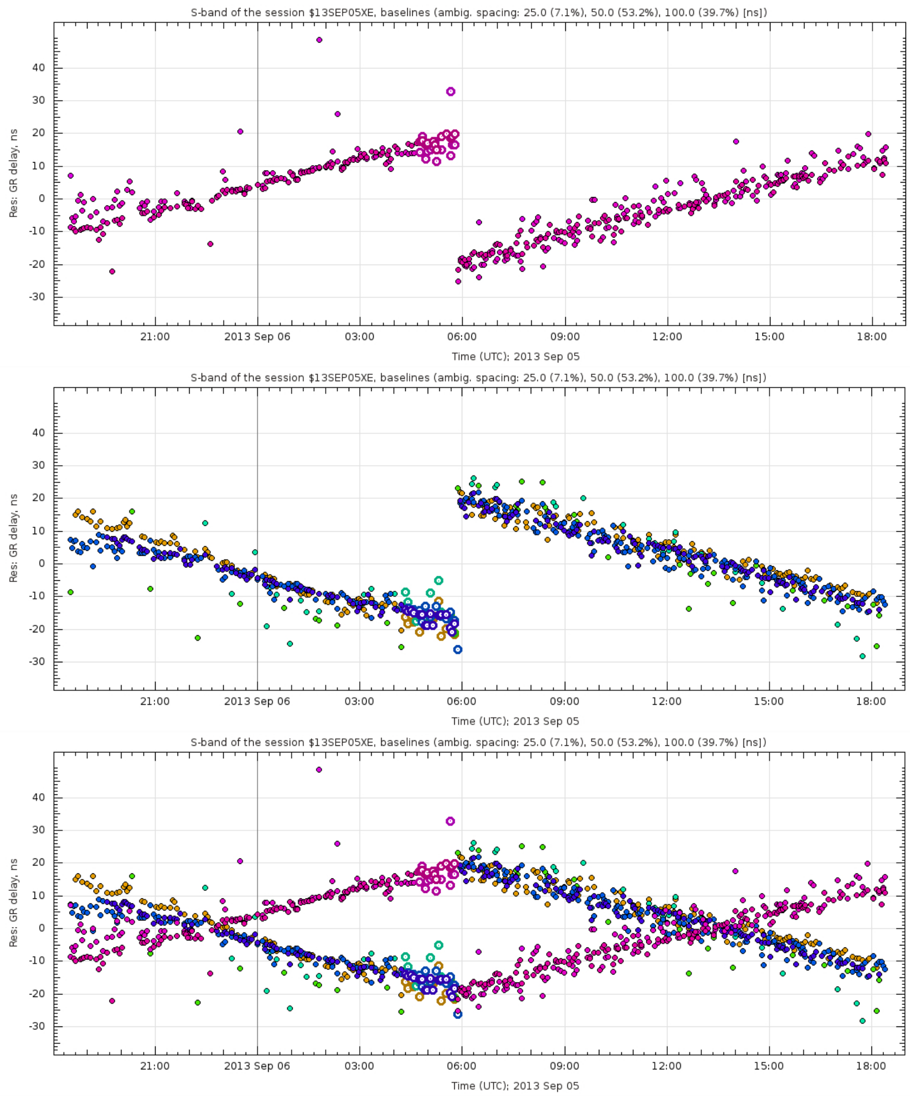


Figure 7.10: Session 13SEP05XE: group delay residuals. Processing a clock break.

Left click on the button *F+*, and choose station *SVETLOE*. All baselines with SVETLOE will be visible (see the bottom part of Fig. 7.10).

Press the *Ctrl+b* key combination. The software will use the marked points to figure out the station at which the clock break occurred and when it occurred. Also, the software will estimate the magnitude of the clock break and adjust the residuals for its value.

Select all baselines using the button **+*, and press the *Process* button to refresh the residuals. At this stage you should get a distribution such as the one shown in Fig. 7.11.

If necessary, recalculate the ambiguities (using the *Ambig* button), update the residuals (using the *Process* button) and re-estimate the magnitude of the clock break (using the *Ctrl+b* key combination).

Because the station and the epoch of the clock break is known, every time a user presses the *Ctrl+b* keys, νSolve will use these pieces of information to calculate the magnitude of the break; no other point selection is necessary. Also, sometimes it happens that several stations have clock breaks or that a station has several clock

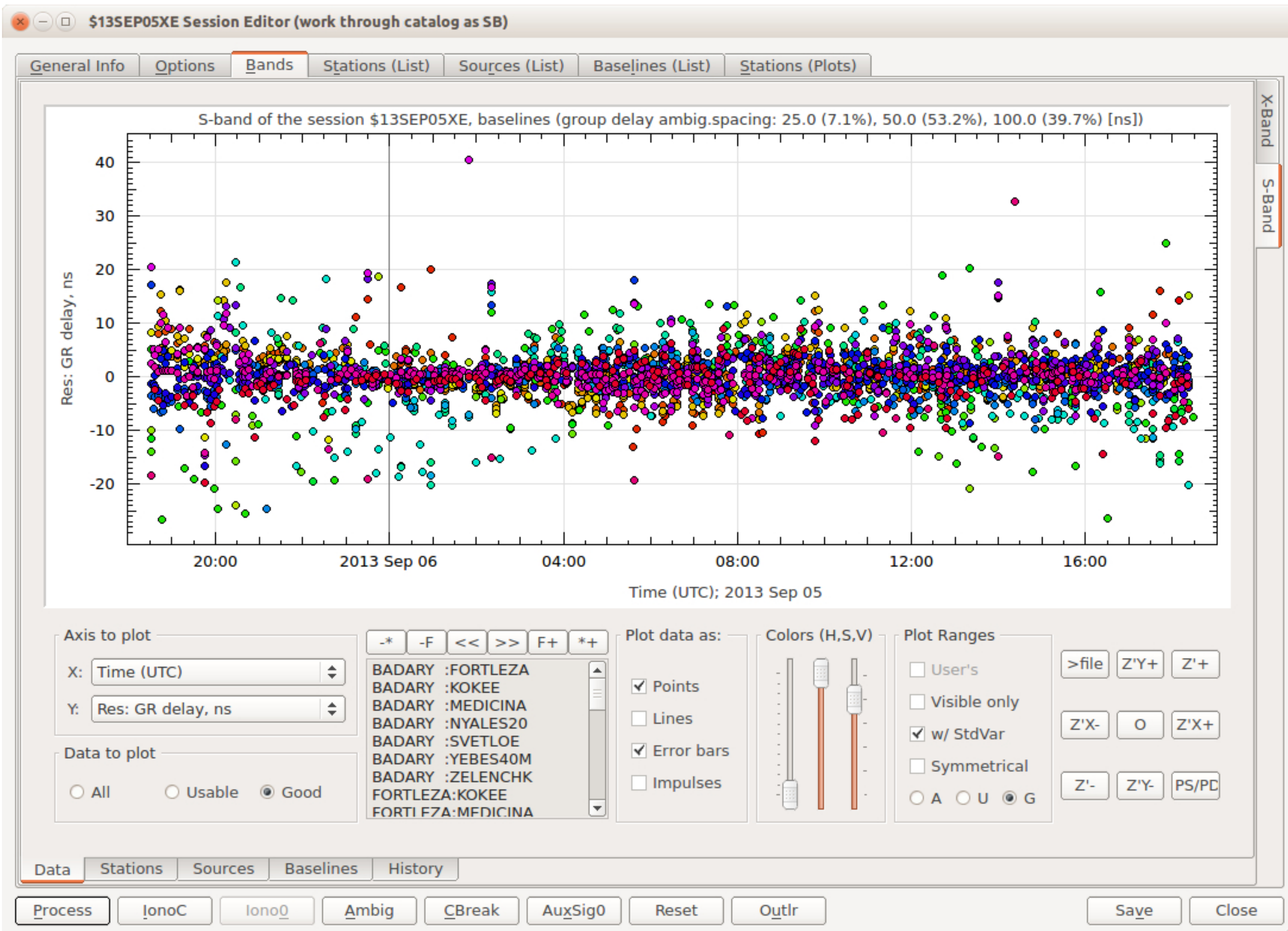


Figure 7.11: Session 13SEP05XE: group delay residuals on the S-band. The clock break at SVETLOE is taken into account.

breaks. In this case you need to mark and then press the *Ctrl+b* keys to notify νSolve about each clock break. One by one, all known clock breaks will be included in the estimation procedure.

You do not need to perform the procedure of selecting points as described above. The software checks the marked points to figure out the station name (it uses the most frequent name) and the epoch of the break (it takes the latest epoch from the marked points). So, if you are sure, it is enough to mark just two baselines with a clock break without any operations of baseline selection and deselection.

Because we resolved the group delay ambiguities and fixed the clock break at SVETLOE, we can extend our parameterization model and include zenith delays and station positions as local parameters as shown in Fig. 7.12. Select the X-band sub-tab and press the *Process* button to obtain a new solution. You should get a distribution of residuals similar to the top plot of Fig. 7.13. As one can see, there are several points that have residuals on the level of $13 - 15ns$. These are examples of large outliers. Before continuing, we want to remove them. Mark these points, as shown in the middle plot of the figure, and press the *Ctrl+x* key combination. Repeat the solution to refresh the residuals. You should get a picture as shown in the bottom plot of Fig. 7.13.

Check the residuals for every baseline, repeatedly clicking on the "»" button above the baseline names of the plot, to be sure that there are no any other effects that look like clock breaks.

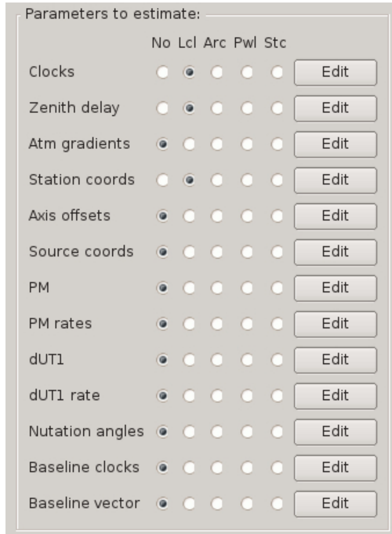


Figure 7.12: Estimated parameters

When you done with X-band, switch to S-band. When a user estimates parameters for a specified type of observable (single band delay, group delay, etc.) and selected band, νSolve evaluates residuals for all bands and observables with respect to the obtained parameters. Therefore, when you switch to the S-band data, the residuals should look completely different, see Fig. 7.14. The reason for this is the influence of the ionosphere. We did not calculate the ionospheric corrections yet; therefore the parameter estimations for the two different frequency bands are different.

Press the *Process* button to recalculate the residuals for this band. If necessary, repeat the procedure for ambiguity resolution.

Now we can set a "standard" number of polynomial coefficients for the clock model. Go to the *Stations (List)* tab and right click in the column *#Clk.Terms* to increase the number of polynomial coefficients to three for each station except the clock reference station. To decrease the number, left click in the column. Usually, we set the number of polynomial clock terms to three to be compatible with CALC/SOLVE. However, sometimes a station's clock behavior can have strongly expressed higher polynomials. In this case you can set up higher polynomial orders. Also, you can set the standard polynomial order during the early stages of data processing. There are no restrictions — just use common sense.

Again, recalculate the residuals and, if necessary, repeat the procedure for ambiguity resolution. Check the residuals for every baseline (using the "»" and "«" buttons) for effects that look like clock breaks. At the end you should get residuals as shown in Fig. 7.15.

Also, for S-band it frequently happens that for some baselines the ambiguity spacings are less than the nominal 100ns value. For this session they are: baseline MEDICINA:YEBES40M (25ns) and other baselines with MEDICINA and baselines with FORTLEZA and ZELENCHK (50ns). We strongly recommend inspecting the residuals at these baselines for unresolved ambiguities and fixing them, if necessary, manually. To check the ambiguity spacings of baselines, you can plot ambiguity spacings as a function of time. Click on the combo box next to the *Y* label of the *Axis to plot* group of the plot and choose *Ambig spacing, ns* to display the data. A double click on a point will open a window with information about the corresponding observation.

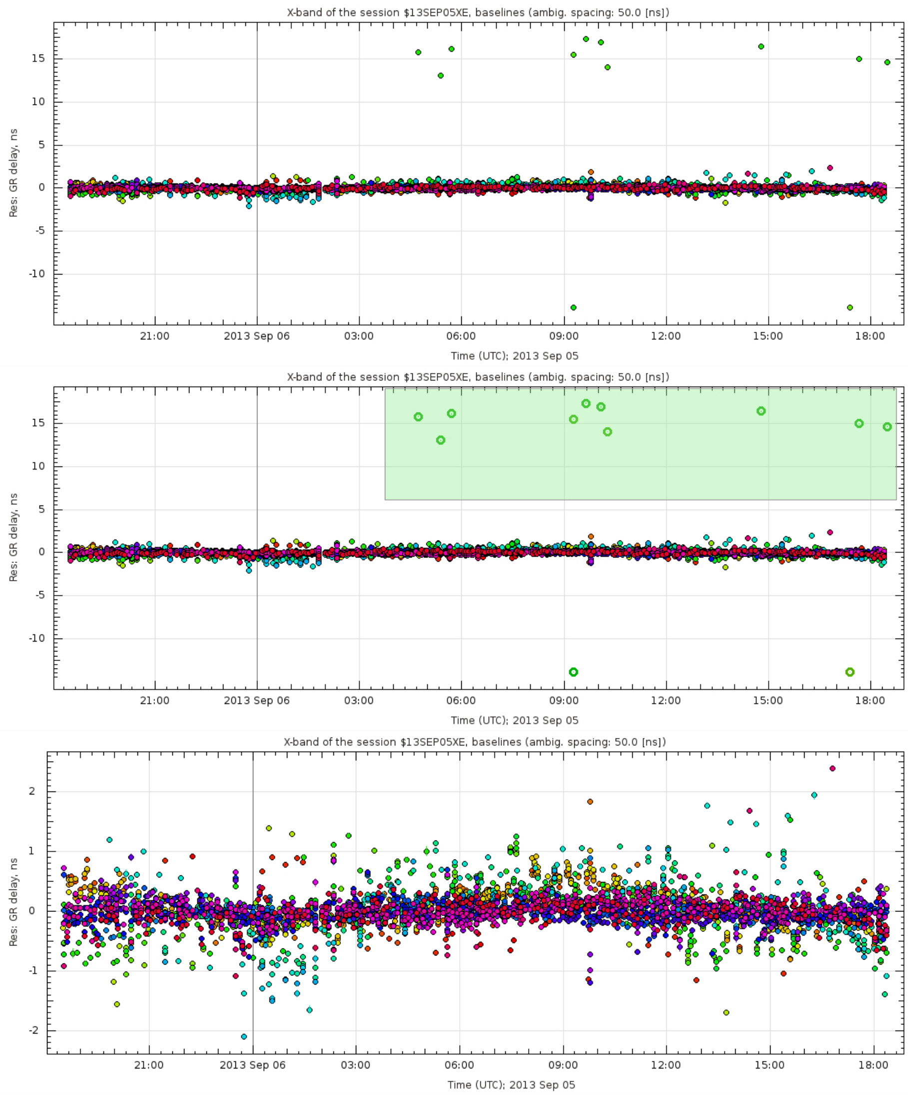


Figure 7.13: Session 13SEP05XE: group delay residuals. Removing large outliers.

7.1.5 Ionosphere correction

To evaluate the ionosphere corrections, press the *IonoC* button at the bottom of the Session Editor window and recalculate the residuals. After this procedure the residuals for X-band will look as shown in Fig. 7.16.

At this stage, when the ionospheric corrections are added to the model, the residuals for X-band and S-band look similar; the difference is only in the standard deviations of observations. In fact, for both cases we have an «ionosphere free combination» of dual frequency observations.

It is worth noting that if there are some unresolved ambiguities or clock breaks, they will affect the ionosphere corrections and, as a result, the residuals of both bands at this stage. Check the baselines one by one. If you notice one of these effects, remove the ionospheric corrections by pressing the *Iono0* button, find the band where the effect appears, and fix it. Then, repeat the procedure of calculating the ionosphere corrections.

Once the ionospheric corrections have been calculated, all other solutions are made using the observations at

Figure 7.14: Session 13SEP05XE: group delay residuals on the S-band.

X-band.

7.1.6 Obtaining a full solution

Now we can set up the «standard» set of parameters. Usually, we estimate clocks and zenith parameters as piecewise-continuous functions, and we treat the station positions, rate of Earth rotation, angles of nutation, and baseline clock offsets as local parameters, see Fig. 7.17.

To configure a piecewise-continuous (PWL) function, press the *Edit* button (see the figure). For the PWL mode, there are two values — the interval of a piece and the magnitude of the constraints that have to be applied to the variations of the parameter. By default, the interval for the clocks and for the zenith delays is one hour. The constraints for clocks are 72 ps/hr and for zenith delays are 1.1992 cm/hr. These values conform to the default values of interactive SOLVE, 2.00 D-14 and 40.00 ps/hr, respectively. For the atmospheric gradients, the default value for the interval is 28.8 hr, which is supposed to be greater than the length of a session. In this case, νSolve, as well as interactive SOLVE, will adjust the PWL interval to the length of the session. The default constraints for the gradients are loose; currently, they are 10^9 m/hr.

If you turned on the baseline clock offsets, you need to select the baselines for which the clock offsets will

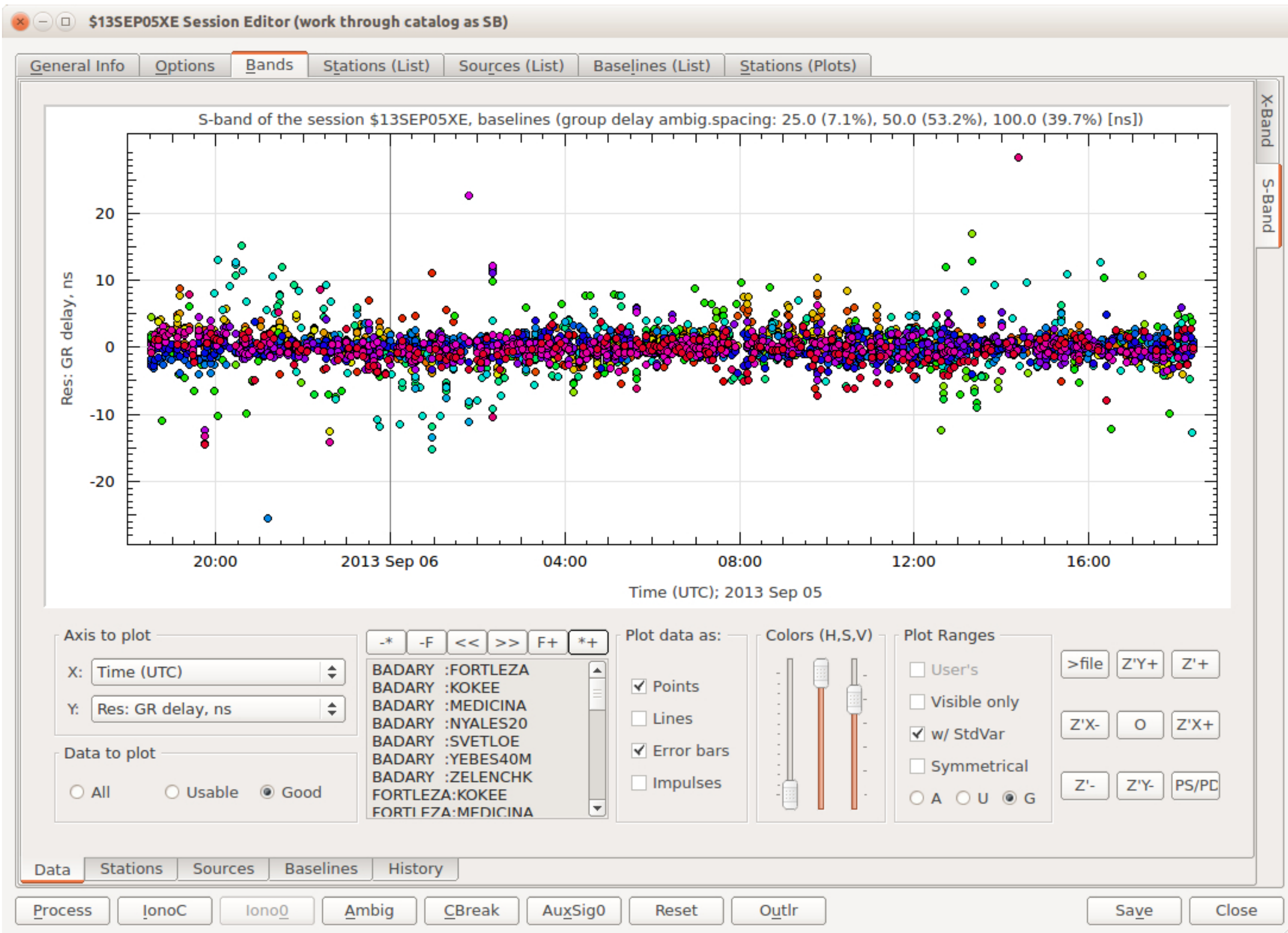


Figure 7.15: Session 13SEP05XE: group delay residuals on the S-band.

be estimated. In contrast to the flags for other estimated parameters, the "estimate clock offset" flag for each baseline is turned off by default. To turn these flags on, go to the tab *Baselines (List)* and turn on the proper flag as described in the subsection 6.2.6. Not all baselines require estimation of a clock offset. Use this parameter only for baselines that reveal significant clock offsets.

Press the *Process* button to estimate parameters. Check for large outliers. Fig. 7.18 displays the residuals. As one can see, there are a few observations that have large residuals. We exclude them from the solution. It is (relatively) safe because later we will add into the analysis all observations that were previously excluded or were never included at all, if they have residuals less than three sigmas. On the other hand, manually exclude observations that are really large outliers (i.e., that have residuals of, perhaps, eight sigmas and higher, see plots of *Normalized residuals*).

Also, it is worthwhile to check the obtained solutions. The estimations of the local parameters are printed in the log output. The estimations of time varying clock and troposphere parameters are plotted on the plot of the *Stations (Plots)* tab. Select *Est.Clocks, ps* as the *Y* axis to check the estimations of clocks, *Est.Zenith, ps* to check the wet zenith delays, and *Est.AtmGrd:N, cm* and *Est.AtmGrd:E, cm* to check the tropospheric gradients in the north and the east directions.

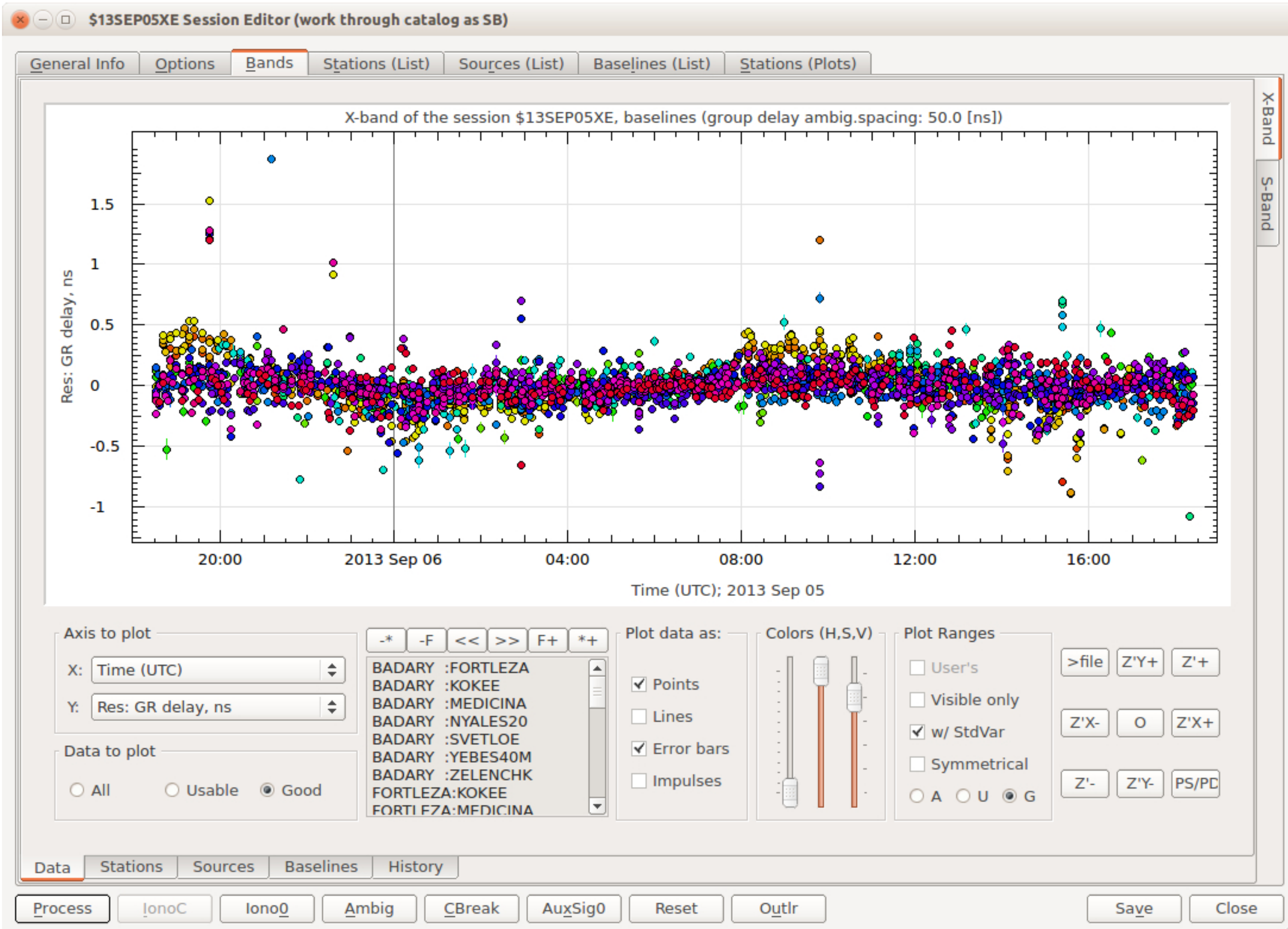


Figure 7.16: Session 13SEP05XE: group delay residuals.

7.1.7 Reweighting of observations

To make a reduced χ^2 close to unity, νSolve (as well as interactive SOLVE) calculates additional sigmas that will be added to the standard deviations of the observations to compute the weights of the observations. The algorithm of calculation of the additional sigmas is described in [8].

Since these calculations are made during data processing, to turn on the procedure of reweighting, check the *Evaluate weight correction* box of the *Reweighting* group at the *Options* tab. When you press the *Process* button next time, the weight corrections will be evaluated. To put them into effect, a user needs to repeat data analysis. This is a converging process. Usually you need to make three to four iterations to obtain the proper additional sigmas.

The weight corrections are calculated in two modes: independently for each baseline and for the whole band (see the *Reweighting mode* radio button in *Options*). Depending on the mode, the user can check the evaluated weight corrections either in the column *Sigma_0* at the tab *Baselines (List)* or in the column σ_0 of the group *Bands* at the tab *General Info*.

There are two shortcut keys, *Alt-2* and *Alt-3*. Pressing these keys are equivalent to clicking the *Process* button two and three times respectively.

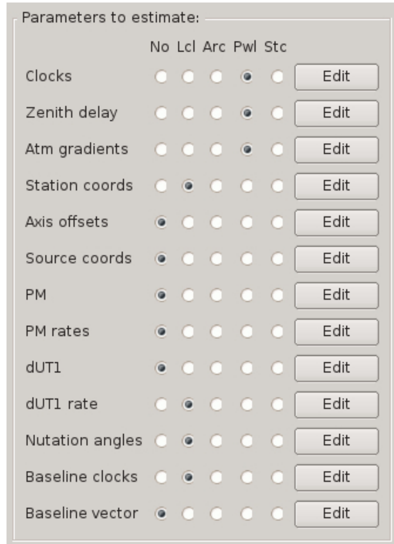


Figure 7.17: Estimated parameters.

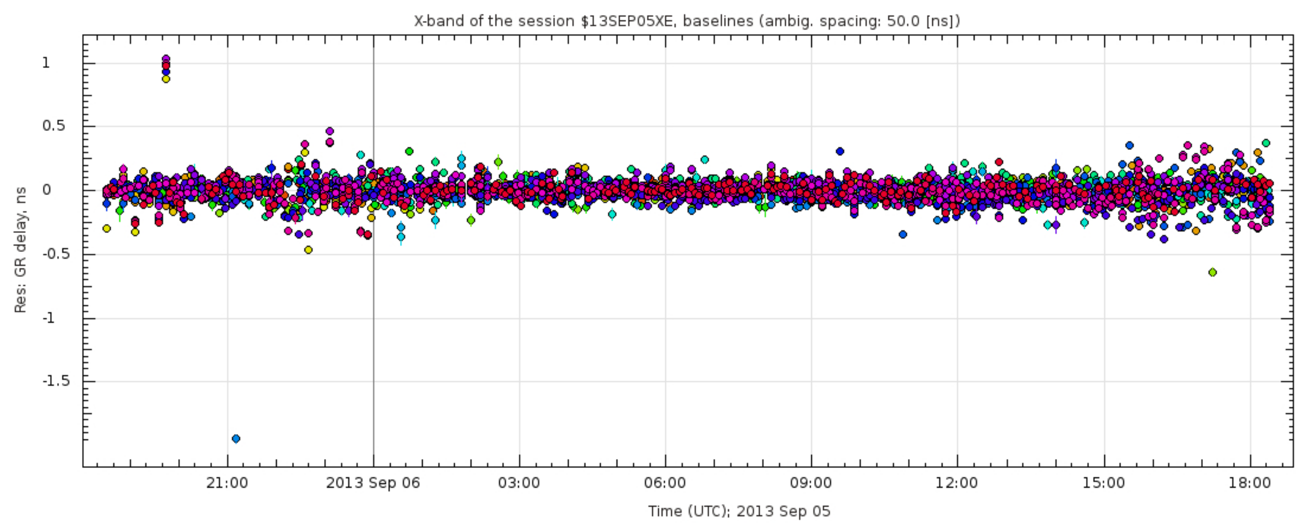


Figure 7.18: Session 13SEP05XE: group delay residuals.

7.1.8 Outlier processing

When the procedure of reweighting is completed, we can remove outliers. By "outlier" we mean an observation with an absolute normalized residual greater than a user-specified threshold. The residuals are normalized either by a dispersion, as it is described in [7], or by WRMS. The normalization with the dispersion is done if the checkbox *Use SOLVE compatible mode* is «on», otherwise, the WRMS are used.

By default, the threshold is set to three (the normalized residuals are unitless; with some assumptions, this corresponds to 3σ for non-normalized residuals). The procedure is iterative. νSolve searches for the observation with the largest normalized residual, deselects it from the data analysis and obtains a new solution. Then it repeats the procedure. The user can change the maximum number of iterations. By default, this value is equal to 40 (see the *Options* tab).

To initiate the procedure for outlier processing, press the *Outlr* button at the bottom of the Session Editor window. νSolve will start to deselect outliers and recalculate the solution. It can take some time.

By default, when the software recalculates the solution after the elimination of an outlier, the reweighting coefficients are not calculated. After the iterations have finished, make several solutions to refresh the reweighting corrections and keep reduced χ^2 close to unity.

There is also a shortcut, *Alt-4*, that is equivalent to clicking on the *Outlr* button and then pressing the *Alt-3* key combination.

When you get to the stage where there are no outliers to remove, change the action of outlier processing from *Elimination* to *Restoration* at the *Options* tab, in the *Outliers Action* group of radio buttons. Repeat the outlier processing. With the restoration action, νSolve includes in the data analysis all observations that have normalized residuals less than the threshold.

Repeat the elimination and restoration actions. At the end, there should not be any observations that can be either eliminated or restored.

At this stage, check the baseline clock offsets again. When the reweighting is done, the estimations will not be so optimistic, and the number of significant clock offsets will decrease. If necessary, repeat the procedure of outlier processing.

7.1.9 Saving the results

To save the edited session, press the *Save* button at the bottom of the Session Editor window. The session will be saved in the corresponding format. Also, a file in the interactive SOLVE *spoolfile* format will be generated.

7.2 Using a source structure model

The recent VGOS observations showed that the effect of source structures becomes detectable in the broadband group delays. To take into account this effect a simple multi point source structure model is implemented in νSolve, see [4] for details.

To turn on using the model, a user should check on the checkbox *Apply source structure model* of the "General configure editor" or "Options" tab of the "Session editor". A source for which the model should be applied have to have the attribute "Apply the multi point source structure model" set to «on». It can be done with the source attribute editor (see *6.2.5 Source Attributes Editor*) or clicking at the corresponding row of the column *UseSSM* of the sources list, *6.2.5 Tab «Sources (List)»*).

Components of the model should have non-zero position and ratio of brightness. To edit the parameters of a component manually, use the source structure model component Editor (see Fig. 6.12).

Another option to provide parameters of the model is to set up a file with a list of sources and their source structure model components. Using of such file is configuring in the tab *External a priori and models* (see the subsection *4.2.3 Applying different models and using external a priori information*). If the file is exist and the checkbox *Source structure model* is on, then the file will be read after loading a session.

The file has the following format. Any string that starts with a char «$», «#», «*» or «/» is considered as a comment line. Each line consist of a token (case insensitive) and its value pairs:

```
Token:Value
```

A line that has a token-value pair `Src:<SourceName>` specifies a source and a first component of the model. A pair `SSM_T:MP` determines that the type of a source structure model is the multi point model. Tokens `x` and `y` provide relative coordinates of the component. A token `K` sets the brightness ratio and a token `B` – a difference of spectral indices. Tokens `ER` , `EK` and `EB` specify which parameters should be estimated: position of a component, ratio k or difference of spectral indices β correspondingly. A token `T` specifies an epoch since that the model is valid. The tokens `x` , `y` and `k` are mandatory if the model type is `MP` . If other parameters are not specified, they will be zero (β), «no» (`ER` , `EK` and `EB`) and some very early epoch for `T` . If a source structure model has more than one secondary component, the token `Src:` should be omitted.

For example, the records

```
Src:0016+731 SSM_T:MP i:1 x:-0.5970 y: 0.0894 K:0.1850 B: 4.2510  ER:No EK:No EB:No
                      i:2 x:-0.7031 y: 0.7141 K:0.0852 B: 0.8741  ER:No EK:No EB:No


Src:0016+731 SSM_T:MP i:1 x:-0.5231 y: 0.0627 K:0.5320 B:-0.4592  ER:No EK:No EB:No T:2018/01/01
```

specifies that if a first epoch of observations is before January 1, 2018 then the model with two secondary components will be used, otherwise a model with one secondary component will be applied.

If the brightness ratio, K, is not fall into realistic interval,]0..1[, or both coordinates, x and y, are zeros, then the model will be turned off. It can be useful when you have a time tag «T:» to specify since when the model should not be applied.

Number of spaces between tokens can be arbitrary. The tokens `:1 }, {\verb` :2 , etc. are not used, they are added mostly for user convenience.

An example of such file is distributed along with the software, see `data/glo.ssm` file. Starting with the distribution version 0.7.1, this file contains results of estimation of the parameters of the source structure model from available at this time VGOS sessions. Currently, the estimations are available for several radio sources: 0016+731, 0059+581, 0119+115, 0552+398 and 3C371. In future, this list, perhaps, will be extended.

To estimate parameters of a model component, a user should set to "Lcl" the corresponding checkbox, *Source structure model* of the widget group *Parameters to estimate* of the tab *Operation*. In contrast to other estimated parameters, the components of the model are accumulating the estimated values. It means that after each iteration the obtained estimations are added to their a priori values. It is done to find out how meaningful the estimations are. The model is highly non linear, it is strongly depend on initial (a priori) values. If a model is real, than with each iteration the estimations will go smaller and smaller, the positions of a component will be in a circle of tens mas, the k ratio will be bigger than 0 and less than 1. Everything else should be considered as misfitting.

Chapter 8

Scripting support

8.1 ECMAScript in νSolve

The scripting abilities in νSolve are in development stage. The software uses the script engine that is provided by Qt library (QtScript module). This is a realization of ECMAScript, a standardized version of JavaScript – simple, powerful and flexible object oriented scripting language. Documentation and user guides are available on the Net, one of the link is:

`https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide`

To realize scripting in νSolve we made some classes and objects accessible to the script engine. Since this feature of the software is in active development phase, the list of available for script objects will be extended in the future.

To invoke a script in νSolve a user should provide a file name of the script with «-t» option, e.g.:

```
> nuSolve -t pia4INT.js
```

Here the file `pia4INT.js` is a script that executes all post import actions for INT type of a VLBI session, see 4.2.4. This file is a part of nusolve distribution and can be found in a directory *scripts* of the distribution.

If a file cannot be found in the current directory, νSolve will search a file with the provided name in the system wide directory (can be altered during execution of `configure` script, see Chapter *2 Installation*). This feature allows a user to skip path to the scripts that are provided by the distribution.

When a user invokes νSolve to execute a script, the software uses the standard or altered configuration. However, it does not save changes to the configuration that were made in a script. So it is safe to modify options, models, parameters, etc.

In the following sections we discuss the internal objects that are accessible to the script engine.

8.2 Software set up in scripts

Changing the software setup (see Chapter 4) in a script is done through an object *setup*. The properties of the object are shown on the table Tab. 8.1.

The properties have read/write access, so user can change them. After end of script execution, the modified properties will not be saved (in contrast to the interactive mode). An example of using the object *setup*:

```
setup.path2SpoolFileOutput = 'spoolfiles-tests';
setup.have2KeepSpoolFileReports = true;
print('Path to spool files: ' + setup.path2SpoolFileOutput);
print('Have to keep spool files: ' + setup.have2KeepSpoolFileReports);
```

will generate the following output:

```
Path to spool files: spoolfiles-tests
Have to keep spool files: true
```

Type	Property	Access	Meaning
String	path2Home	Read/Write	a path to software home directory
String	path2CatNuInterfaceExec	Read/Write	a path to the Catalog <–> nuSolve Interface
String	path2DbhFiles	Read/Write	a path to VLBI sessions in DBH format
String	path2VgosDbFiles	Read/Write	a path to VLBI sessions in vgosDb format
String	path2VgosDaFiles	Read/Write	a path to VLBI sessions in vgosDa format
String	path2APrioriFiles	Read/Write	a path to search for a priori files
String	path2MasterFiles	Read/Write	a path to read master files
String	path2SpoolFileOutput	Read/Write	a path to write a spool file
String	path2NotUsedObsFileOutput	Read/Write	a path where to put observations info
String	path2ReportOutput	Read/Write	a path where to save reports in the spool file format
String	path2NgsOutput	Read/Write	a path where to store NGS files
String	path2PlotterOutput	Read/Write	a path to plotter's output
boolean	have2UpdateCatalog	Read/Write	if *true* the software will use the catalog
boolean	have2MaskSessionCode	Read/Write	save a session with alternative database name
boolean	have2KeepSpoolFileReports	Read/Write	copy a spool file into *path2ReportOutput* directory
boolean	have2LoadImmatureSession	Read/Write	load a session that does not have all data
boolean	have2AutoloadAllBands	Read/Write	automatically load all available bands
String	pwd	Read	an absolute path of the current directory

Table 8.1: Execution control properties of *setup* object.

8.3 Solution configuration in scripts

To modify the configuration of a solution an object *config* is available in a script. The properties of the object are shown on the tables Tab. 8.2 – 8.6. All properties have read/write access, so user can inquire or modify them. For example, the commands in a script

```
config.qualityCodeThreshold = 4;
print('QC threshold = ' + config.qualityCodeThreshold);
```

will generate the following output:

```
QC threshold = 4
```

The first group of properties controls how a solution will be obtained. They are shown on Tab 8.2 and correspond to the general options of software configuration (see subsection 4.2.1 for details).

The first column of the tables displays type of a property. ECMAScript has one primitive type for integers and doubles, «Number». In the table instead of type **Number** the two C++ types are shown (**int** or **double**) to make a user easier to figure out what values are expected by the software. Another set of types are provided by the metaobject «CFG» (like **CFG.VlbiDelayType** on the Tab. 8.2), these types will be discussed later.

The Tab. 8.3 and Tab. 8.4 shows properties that affects processing of outliers and weight correction (as it described in the subsection 4.2.2).

Manipulations with external a priori data (discussed in subsection 4.2.3) are displayed on Tab. 8.5.

The next table, Tab. 8.6, shows properties that specify which contributions will be used in a solution. The contributions were discussed in subsection 4.2.3.

In the last table, Tab. 8.7, there are properties that specify which flyby models should be used in a solution. The flyby models can be adjusted for the two effects: tropospheric zenith delay mapping function and source of cable calibration corrections.

The flyby tropospheric zenith delay mapping function can be switched off, or a user can chose which model to apply: Niell [6] or MTT [5] mapping function. To use the flyby model, the properties «have2ApplyNdryContrib»

Type	Property	Access	Meaning
int	qualityCodeThreshold	Read/Write	Quality Code threshold
int	goodQualityCodeAtStartup	Read/Write	initial Quality Code threshold for non-processed yet session
boolean	useGoodQualityCodeAtStartup	Read/Write	for new session initially use observations with Quality Code of *goodQualityCodeAtStartup* or higher
CFG.VlbiDelayType	useDelayType	Read/Write	type of delay to use
CFG.VlbiRateType	useRateType	Read/Write	type of rate to use
int	activeBandIdx	Read/Write	index of the band to process
boolean	isSolveCompatible	Read/Write	run in interactive SOLVE compatible mode
boolean	useDynamicClockBreaks	Read/Write	estimate clock break parameters in a common solution
boolean	useSolveObsSuppresionFlags	Read/Write	use SOLVE observation elimination flag
CFG.EstimatorPwlMode	pwlMode	Read/Write	mode for piece-wise continuous function for parameters estimated as *PWL*
boolean	doDownWeight	Read/Write	downweight delays
boolean	have2outputCovarMatrix	Read/Write	controls output of a covariance matrix in a spool file

Table 8.2: Execution control properties of *config* object.

Type	Property	Access	Meaning
CFG.OutliersProcessingMode	opMode	Read/Write	outlier processing mode, band-wide or for each baseline
CFG.OutliersProcessingAction	opAction	Read/Write	outlier processing action: remove an outlier from a solution or include it back
double	opThreshold	Read/Write	threshold for residuals to specify an outlier
int	opIterationsLimit	Read/Write	limit for a number of iterations
boolean	opHave2SuppressWeightCorrection	Read/Write	need to turn off weight corrections while running iterations
boolean	opHave2NormalizeResiduals	Read/Write	use normalized residuals to determine outliers
boolean	opIsSolveCompatible	Read/Write	evaluate the normalized residuals in SOLVE compatible mode

Table 8.3: Outlier processing properties of config object.

and «have2ApplyNwetContrib» should be set to **false** and the property «flybyTropZenithMap» should be one of «CFG.TZM_NMF» or «CFG.TZM_MTT». The GUI mode of the software will not allow a user to apply both the flyby model and the contributions. In the script mode it is a user responsibility to not use the effect two times.

Starting with version 0.7.5 of the software νSolve is capable to accumulate cable calibration corrections from different sources (FS log files, CDMS or proxy (PCMT) cable corrections). When these data are available, the a user can specify what type of cable calibration corrections should be used by adjusting the property «flybyCableCalSource». The allowable values are listed in the table Tab. 8.8: «CCS_DEFAULT», «CCS_FSLG», «CCS_CDMS» and «CCS_PCMT».

The metaobject «CFG» provides types of for communication with the object *config*. Tab. 8.8 lists such types and their values.

Below there are several examples of using the object *config* in scripts. To acquire information about current control properties a user can run put into a script the following code:

Type	Property	Access	Meaning
boolean	doWeightCorrection	Read/Write	switches the evaluation of weight corrections
CFG.WeightCorrectionMode	wcMode	Read/Write	weight correction mode, band-wide or for each baseline
boolean	useExternalWeights	Read/Write	use an external file with precalculated weights
String	extWeightsFileName	Read/Write	a name of the external file

Table 8.4: Weight correction properties of config object.

Type	Property	Access	Meaning
boolean	useExtAPrioriSitesPositions	Read/Write	use external site positions
boolean	useExtAPrioriSitesVelocities	Read/Write	use external site velocities
boolean	useExtAPrioriSourcesPositions	Read/Write	use external source positions
boolean	useExtAPrioriErp	Read/Write	use external ERP
boolean	useExtAPrioriAxisOffsets	Read/Write	use external axis offsets
boolean	useExtAPrioriHiFyErp	Read/Write	use external model for subdiurnal ERP variations
boolean	useExtAPrioriMeanGradients	Read/Write	use external mean atmospheric gradients
boolean	useExtAPrioriSsm	Read/Write	use external file with source structure models
String	extAPrioriSitesPositionsFileName	Read/Write	a file name for site positions
String	extAPrioriSitesVelocitiesFileName	Read/Write	a file name for site velocities
String	extAPrioriSourcesPositionsFileName	Read/Write	a file name for source positions
String	extAPrioriErpFileName	Read/Write	a file name for ERP
String	extAPrioriAxisOffsetsFileName	Read/Write	a file name for axis offsets
String	extAPrioriHiFyErpFileName	Read/Write	a file name for subdiurnal ERP variations
String	extAPrioriMeanGradientsFileName	Read/Write	a file name for mean atmospheric gradients
String	extAPrioriSsmFileName	Read/Write	a file name for external source structure model
String	eccentricitiesFileName	Read/Write	a file name for eccentricities

Table 8.5: Use of external a priori properties of config object.

Type	Property	Access	Meaning
boolean	have2ApplyPxContrib	Read/Write	apply contributions for the polar motion, X-component
boolean	have2ApplyPyContrib	Read/Write	apply contributions for the polar motion, Y-component
boolean	have2ApplyEarthTideContrib	Read/Write	apply contributions for solid Earth tides
boolean	have2ApplyOceanTideContrib	Read/Write	apply contributions for ocean tides loading
boolean	have2ApplyPoleTideContrib	Read/Write	apply contributions for pole tide deformations
boolean	have2ApplyUt1OceanTideHFContrib	Read/Write	apply contributions for subdiurnal UT1 variations
boolean	have2ApplyPxyOceanTideHFContrib	Read/Write	apply contributions for subdiurnal polar motion
boolean	have2ApplyNutationHFContrib	Read/Write	apply contributions for libration in ERP (CALC 10)
boolean	have2ApplyUt1LibrationContrib	Read/Write	apply contributions for libration in UT1 (CALC 11)
boolean	have2ApplyPxyLibrationContrib	Read/Write	apply contributions for libration in polar motion (CALC 11)
boolean	have2ApplyOceanPoleTideContrib	Read/Write	apply contributions for ocean pole tide loading
boolean	have2ApplyFeedCorrContrib	Read/Write	apply contributions for feed horn rotation
boolean	have2ApplyTiltRemvrContrib	Read/Write	apply contributions for axis tilt remover
boolean	have2ApplySsm	Read/Write	turn on/off using the source structure model
boolean	have2ApplyAxisOffsetContrib	Read/Write	apply contributions for axis offsets
boolean	have2ApplyNdryContrib	Read/Write	apply contributions for refraction, hydrostatic atmosphere
boolean	have2ApplyNwetContrib	Read/Write	apply contributions for refraction, wet atmosphere
boolean	have2ApplyOldOceanTideContrib	Read/Write	apply contributions for old model of ocean tides
boolean	have2ApplyOldPoleTideContrib	Read/Write	apply contributions for old model of ocean pole tides

Table 8.6: Use of contributions properties of config object.

```
print('QC threshold                 : ' + config.qualityCodeThreshold);
print('Good QC threshold @startup  : ' + config.goodQualityCodeAtStartup);
print('use QC threshold @startup   : ' + config.useGoodQualityCodeAtStartup);
print('Type of delay to use        : ' + config.useDelayType);
print('Type of rate to use         : ' + config.useRateType);
print('Active band index           : ' + config.activeBandIdx);
print('Run in SOLVE compatible mode: ' + config.isSolveCompatible);
print('Estimate clock breaks       : ' + config.useDynamicClockBreaks);
print('Use SOLVE suppression flag  : ' + config.useSolveObsSuppresionFlags);
print('PWL parameters model        : ' + config.pwlMode);
print('Make downweighting          : ' + config.doDownWeight);
```

The output is depend on the current configuration, here how can look:

```
QC threshold               : 5
Good QC threshold @startup  : 8
```

Type	Property	Access	Meaning
CFG.TropZenithMap	flybyTropZenithMap	Read/Write	Specifies a model of mapping function;
CFG.CableCalSource	flybyCableCalSource	Read/Write	Specifies a source of origin of cable calibration corrections.

Table 8.7: Properties of config object that control flyby models.

Type	Values	Meaning
VlbiDelayType	VD_NONE	do not use delays
	VD_SB_DELAY	use single band delays
	VD_GRP_DELAY	use group delays
	VD_PHS_DELAY	use phase delays
VlbiRateType	VR_NONE	do not use rates
	VR_PHS_DELAY	use phase rates
WeightCorrectionMode	WCM_BAND	band-wide weight correction
	WCM_BASELINE	baseline dependent weight correction
OutliersProcessingMode	OPM_BAND	band-wide outlier processing
	OPM_BASELINE	baseline dependent outlier processing
OutliersProcessingAction	OPA_ELIMINATE	remove outliers
	OPA_RESTORE	include back outliers
EstimatorPwlMode	EPM_INCRATE	incremental rates model of PWL parameters
	EPM_BSPLINE_LINEA	linear B-Splines model of PWL parameters
	EPM_BSPLINE_QUADR	quadratic B-Splines model of PWL parameters
TropZenithMap	TZM_NONE	do not use flyby mapping functions
	TZM_NMF	use Niell mapping function
	TZM_MTT	use MTT mapping function
CableCalSource	CCS_DEFAULT	use the default source of cable calibrations
	CCS_FSLG	use cable calibrations from FS log file (if available)
	CCS_CDMS	use CDMS cable calibrations (if available)
	CCS_PCMT	use proxy (PCMT) cable calibrations (if available)

Table 8.8: Properties of metaobject **CFG**.

```
use QC threshold @startup   : true
Type of delay to use        : CFG.VD_SB_DELAY
Type of rate to use         : CFG.VR_NONE
Active band index           : 0
Run in SOLVE compatible mode: true
Estimate clock breaks       : true
Use SOLVE suppression flag  : true
PWL parameters model        : CFG.EPM_INCRATE
Make downweighting          : false
```

To switch type of delays from the single band to the group delay and set the realization of piece-wise continuous parameters with linear B-splines a user can write:

```
config.useDelayType = CFG.VD_GRP_DELAY;
config.pwlMode = CFG.EPM_BSPLINE_LINEA;
print('Type of delay to use        : ' + config.useDelayType);
print('PWL parameters model        : ' + config.pwlMode);
```

The result of executing the code will be:

```
Type of delay to use        : CFG.VD_GRP_DELAY
PWL parameters model        : CFG.EPM_BSPLINE_LINEA
```

8.4 Set up estimated parameters in the scripts

Another object that is available in scripts is a parameter descriptor, *parsDescript*. The main purpose of the object is to specify which parameters and how will be estimated in a solution. Its meta object in scripts is called

Parameters and have two properties, *ParIdx* and *ParMode*, that determine a type of a parameter and assumed model. On Tab. 8.9 values of available models of a parameter are shown. The kinds of estimated parameters are displayed on Tab. 8.10. The values of both properties of the metaobject, *ParIdx* and *ParMode*, are used as arguments to set up the estimated parameters.

Type	Values	Meaning
ParMode	EstimateNo	do not estimate
	EstimateArc	estimate as arc parameter
	EstimateLocal	estimate as local parameter
	EstimatePwl	estimate as PWl parameter
	EstimateStochastic	estimate as stochastic parameter

Table 8.9: Property *ParMode* of metaobject **Parameters**.

Type	Values	Meaning
ParIdx	Clocks	station clocks
	Zenith	wet zenith delay
	AtmGrad	atmospheric gradients
	Cable	cable calibration coefficient
	AxisOffset	axis offset
	StnCoo	station positions
	StnVel	station velocities
	SrcCoo	source coordinates
	SrcSsm	parameters of a source structure model
	PolusXy	polar motion
	PolusXyR	polar motion rates
	PolusUt1	d(UT1)
	PolusUt1R	d(UT1) rates
	PolusNut	nutation angles
	PolusNutR	nutation angles rates
	Bl_Clk	baseline clocks
	Bl_Length	baseline length
	Test	test purposes

Table 8.10: Property *ParIdx* of metaobject **Parameters**.

The object *parsDescript* allows a user to control the estimated parameters in his/her scripts. The estimated parameters were discussed in subsection 4.2.2. To change a state of a parameter a user calls object related functions, that in ECMAScript have a term «methods». Currently the following methods are implemented:

unsetAllParameters(): turn off all estimated parameters;

unsetParameter(ParIdx idx): turn off a parameter of index *idx*;

setMode4Parameter(ParIdx idx, ParMode mode): sets a parameter of the index *idx* to the mode *mode*;

unsetParameters(ParIdx idxs[ ]): turn off parameters from the array *idxs[]*;

setMode4Parameters(ParMode mode, ParIdx idxs[ ]): sets parameters from the array *idxs[]* to the mode *mode*;

setConvAPriori(ParIdx idx, double d): for the parameter *idx* sets the value of a priori standard deviation to *d* for «local» or «arc» mode;

setPwlAPriori(ParIdx idx, double d): for the parameter *idx* sets the value of a priori standard deviation to *d* for «PWL» mode;

setStocAPriori(ParIdx idx, double d): for the parameter *idx* sets the value of a priori standard deviation to *d* for «stochastic» mode;

setWhiteNoise(ParIdx idx, double d): for the parameter *idx* sets the value of the ruled white noise to *d* for «stochastic» mode;

setArcStep(ParIdx idx, double d): for the parameter *idx* sets the value of the interval between segments to *d* [days] for «arc» mode;

setPwlStep(ParIdx idx, double d): for the parameter *idx* sets the value of the interval between segments to *d* [days] for «PWL» mode;

setPwlNumOfPolynomials(ParIdx idx, int n): for the parameter *idx* sets the value of the number of polynomial terms to *n* for «PWL» mode;

Examples of using *parsDescript*. To estimate only station clocks as local parameters a user can write

```
parsDescript.unsetAllParameters();
parsDescript.setMode4Parameter(Parameters.Clocks, Parameters.EstimateLocal);
```

To estimate clocks, zenith delays, station positions and baseline clocks as local parameters:

```
var idxArr = new Array(4);
idxArr[0] = Parameters.Clocks;
idxArr[1] = Parameters.Zenith;
idxArr[2] = Parameters.StnCoo;
idxArr[3] = Parameters.Bl_Clk;
parsDescript.unsetAllParameters();
parsDescript.setMode4Parameters(Parameters.EstimateLocal, idxArr);
```

If a user wants to estimate clocks and delays as «PWL» functions with an interval 30 minutes between nodes:

```
parsDescript.setPwlStep(Parameters.Clocks, 0.5/24.0);
parsDescript.setPwlStep(Parameters.Zenith, 0.5/24.0);
parsDescript.setMode4Parameter(Parameters.Clocks, Parameters.EstimatePwl);
parsDescript.setMode4Parameter(Parameters.Zenith, Parameters.EstimatePwl);
```

8.5 Manipulations of input/output operations for a VLBI session

An object that performs read/write operations with a VLBI session is called *handler*. It has three properties that control which files should be read and what software should expect in that files. The Tab 8.11 these properties are shown.

Type	Property	Access	Meaning
String	fileName	Read/Write	input file name
String	fileNameAux	Read/Write	the name of auxiliary file (if necessary)
String	inputType	Read/Write	type of input data: "DBH" (database handler format), "VDB" (vgosDb set of files) or "VDA" (vgosDa ASCII file)

Table 8.11: Properties of *handler* object.

If νSolve is configured to read databases in the catalog aware mode (as it described in subsection 4.1.2 or by the command line option «-c»), the property *fileName* can be either a database name (e.g., 17DEC08XU) or a a database name with version (e.g., 17DEC08XU_V004). If a file with the second database has a name that is not following IVS naming convention, a user can provide it using the property *fileNameAux*.

To read a database from local files it is necessary to provide full file name with its path, either absolute or relative to the path to database files as it was set up in νSolve preferences, see subsection 4.1.1. The same is true for non-standard name of the second band.

To read data in the vgosDb format, a user have to provide full file name of the wrapper file with either absolute or relative (to preconfigured directory) path. A value of the property *fileNameAux* in this case is ignored.

To read data in the vgosDa format, a user have to provide a file name with either absolute or relative (to preconfigured directory) path. A value of the property *fileNameAux* in this case is ignored too.

The object *handler* has the following methods:

importSession(): reads a VLBI session in DBH, vgosDb or vgosDa format. The file name and type have to be defined;

performPia(): performs the post-import actions as it was set up by a user (see subsection 4.2.4);

generateReport(bool isExtended=false): generates a report in spool file format, if an argument is present and it is **true**, the report will include additional information on observations;

generateReport4StcPars(): creates ASCII files with solutions for stochastic parameters;

generateReport4Tzds(): exports values of total zenith delays into ASCII files;

generateAposterioriFiles(): stores estimated coordinates of sources, positions and velocities of stations in a format of external *a priori files*.

saveResults(): saves the editing information in a new version (either DBH or a wrapper file);

saveDataAsVgosDa(): saves the session in the vgosDa format;

saveDataAsVgosDb(): saves the session in the vgosDb format;

exportDataToNgs(): exports available data into NGS format;

addUserComment2Report(String userComment): adds a comment string «userComment» to the spool file output.

For example, assuming νSolve works through catalog subsystem, to read a VLBI session in DBH format:

```
handler.fileName = "17DEC08XU";
handler.inputType = "DBH";
handler.importSession();
```

or, if a user wants to use local files and specify an absolute path:

```
handler.fileName = "/home/slb/500/databases/ints/12MAY10XU_V004";
handler.inputType = "DBH";
handler.importSession();
```

The same code using a relative path:

```
handler.fileName = "ints/12MAY10XU_V004";
handler.inputType = "DBH";
handler.importSession();
```

In the last example the default path to database files in the configuration of νSolve software is set to «/home/slb/500/databases» directory.

Reading a VLBI session in vgosDb format is similar:

```
handler.fileName = "/home/slb/500/vgosDb/2012/12MAY10XU/12MAY10XU_V006_iGSFC_kall.wrp";
handler.inputType = "VDB";
handler.importSession();
```

or, assuming the default directory for vgosDb files is «/home/slb/500/vgosDb»:

```
handler.fileName = "2012/12MAY10XU/12MAY10XU_V006_iGSFC_kall.wrp";
handler.inputType = "VDB";
handler.importSession();
```

8.6 The object «session»

The object *session* represents a VLBI session. To access session data, it should be loaded first using the object *handler*. The object *session* is a complex object, it provides access to other objects like *band*, *station*, etc.

The Tab. 8.12 lists basic properties of a session.

Type	Property	Access	Meaning
boolean	isOk	Read only	a status of the session
String	name	Read only	a name of the session
String	networkSuffix	Read only	a network dependent char of a database name
String	sessionCode	Read only	a session code from a master file
String	networkID	Read only	VLBI network code, if known
String	description	Read only	description of a session
String	officialName	Read only	name of a session according to a master file
String	correlatorName	Read only	name of a correlator
String	submitterName	Read only	a name of an agency that submits the session to IVS
String	schedulerName	Read only	a name of an agency that scheduled the observations
String	correlatorType	Read only	a type or a name of a correlator
String	piAgencyName	Read only	PI agency responsible for a session

Table 8.12: Session properties.

For example, after reading data for the session 12MAY10XU_V004 the script commands

```
if (session.isOk)
{
    print('Session name           : ' + session.name);
    print('Session official name  : ' + session.officialName);
    print('Session sessionCode    : ' + session.sessionCode);
    print('Session description    : ' + session.description);
    print('Session scheduled by   : ' + session.schedulerName);
    print('Session submitted by   : ' + session.submitterName);
    print('Session correlator name: ' + session.correlatorName);
    print('Session suffix         : ' + session.networkSuffix);
    print('Session networkID      : ' + session.networkID);
};
```

Will create the following output:

```
Session name           : $12MAY10XU
Session official name  : IN112-131
Session sessionCode    : I12131
Session description    : i12131, INTEN  | geo_export
Session scheduled by   : USNO
Session submitted by   : NASA
Session correlator name: WASH
Session suffix         : U
Session networkID      : INT
```

Another set of session properties are shown on Tab. 8.13.
For the same session the script code

```
print('Session #bands    : ' + session.numOfBands);
print('Session #stations : ' + session.numOfStations);
print('Session #baseline : ' + session.numOfBaselines);
print('Session #sources  : ' + session.numOfSources);
print('Session #observs  : ' + session.numOfObservations);
print('Session created on: ' + session.tCreation);
```

Type	Property	Access	Meaning
int	numOfBands	Read only	number of bands
int	numOfStations	Read only	number of stations
int	numOfBaselines	Read only	number of baselines
int	numOfSources	Read only	number of sources
int	numOfObservations	Read only	number of observations
int	primaryBandIdx	Read only	index of the primary (usually, «X») band
boolean	hasReferenceClocksStation	Read only	**true** if reference clock station is selected
boolean	hasReferenceCoordinatesStation	Read only	**true** if coordinates of at least one station are not estimated or constraints will be applied to the coordinates of at least one station
Date	tCreation	Read only	date when the session was created
Date	tStart	Read only	epoch of the first observation
Date	tFinis	Read only	epoch of the last observation
Date	tMean	Read only	epoch of the mean observation
double	dUt1Value	Read only	returns value of estimated dUT1
double	dUt1Correction	Read only	returns adjustment of dUT1 obtained in a last run
double	dUt1StdDev	Read only	returns standard deviation of estimated dUT1

Table 8.13: Session properties.

```
print('Session started on: ' + session.tStart);
print('Session stopped on: ' + session.tFinis);
print('Session mean epoch: ' + session.tMean);
```

will make the following output:

```
Session #bands    : 2
Session #stations : 2
Session #baseline : 1
Session #sources  : 8
Session #observs  : 22
Session created on: Fri May 11 2012 15:45:24 GMT+0000 (UTC)
Session started on: Thu May 10 2012 18:30:25 GMT+0000 (UTC)
Session stopped on: Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session mean epoch: Thu May 10 2012 18:59:06 GMT+0000 (UTC)
```

The properties of *session* object that have complex type are on Tab. 8.14.

Type	Property	Access	Meaning
array of Bands	bands	Read only	an array of Objects that describe bands
array of Stations	stations	Read only	an array of Objects that describe stations
array of Baselines	baselines	Read only	an array of Objects that describe baselines
array of Sources	sources	Read only	an array of Objects that describe sources
array of Observations	observations	Read only	an array of Objects that describe observations

Table 8.14: Session properties.

The objects *Band*, *Station*, *Baseline*, *Source* and *Observation* allow access to information on particular band, station, baseline, radio source and observation of the session. They will be discussed later.

The object *session* allows a user to inquire and modify data of a VLBI session as well as performs some predefined operations. The first group of its methods allow a user to pick up an object of the type *Station*, *Baseline* or *Source*:

lookUpStation(String key): return an object of type *Station* that has key *key* or **null** if the key was not found;

lookUpBaseline(String key): return an object of type *Baseline* that has key *key* or **null** if the key was not found;

lookUpSource(String key): return an object of type *Source* that has key *key* or **null** if the key was not found;

Here the key *key* is a string of eight (for station and source) or seventeen (for baseline) chars, as names of stations and sources represented in databases. For example, executing the following script sources (assuming the session 12MAY10XU_V004 is already successfully loaded):

```
var key='WETTZELL';
var stn=session.lookUpStation(key);
if (stn != null)
    print('stn = ' + stn.name);
else
    print('Station ' + key + ' was not found');

key='KOKEE';
stn=session.lookUpStation(key);
if (stn != null)
    print('stn = ' + stn.name);
else
    print('Station ' + key + ' was not found');
```

will make the following output:

```
stn = WETTZELL
Station KOKEE was not found
```

Note: in contrast to the property *key*, the property *name* of station, source or baseline has no padding space chars.

The following methods perform predefined actions with session data:

resetAllEditings(): clears all editing information;

clearAuxSigmas(): sets auxiliary standard deviations to zero. The auxiliary standard deviations are calculated to have a reduced $\chi^2 = 1$ for a whole session or baselines, depending on configuration;

suppressNotSoGoodObs(): deselects all observations which have quality code less than value of *Initially use observations with Quality Code of or higher* config option. This feature is useful for a new session;

pickupReferenceClocksStation(): if a reference clock station is not set for the session, sets it up;

pickupReferenceCoordinatesStation(): if a reference coordinate station is not set for the session, sets it up;

setReferenceClocksStation(String key): set a station with key *key* to be a reference clock station. If other station already has this attribute, turn it off. If *key* is not found, do nothing;

checkUseOfManualPhaseCals(): checks the history part of a database for mentioning use of phase calibrations, if found, turn off for such station the use of cable calibrations;

doStdSetup(): performs standard set up, currently it is just a shortcut for invoking suppressNotSoGoodObs(), pickupReferenceClocksStation(), pickupReferenceCoordinatesStation() and checkUseOfManualPhaseCals() methods;

setNumOfClockPolynoms4Stations(int n): sets the number of polynomial terms for clock model. If SOLVE compatibility is set in configuration, the number of the terms for the reference clock station will be set to zero;

calcIono(boolean sbdOnly=false): evaluate the ionospheric corrections. If an optional argument *sbdOnly* is **true**, the corrections are evaluated for single band delays only;

zeroIono(): sets the ionosphere corrections to zero;

scanAmbiguityMultipliers(int bandIdx): scans residuals for a band with the index *bandIdx* and adjust ambiguity multipliers for group delays. If possible, modifies the multipliers to have all triangles closed;

checkClockBreaks(int bandIdx): scans residuals for a band with the index *bandIdx* and check for clock breaks. This option is in developing stage, not all clock breaks can be found;

process(): estimates parameters and evaluate residuals for all bands using current configuration and parameter set up;

eliminateOutliersSimpleMode(int bandIdx, int maxNumOfPasses, double threshold, double upperLimit): performs initial elimination of outliers for a band with the index *bandIdx*. The *maxNumOfPasses* is a number of iterations (this value overrides configuration). This procedure considers as outlier an observation that has absolute value of residual bigger than $threshold \cdot WRMS$ or bigger than *upperLimit* (the last condition is checked if the provided *upperLimit* is greater than zero);

int eliminateOutliers(int bandIdx): performs deselection of observations for a band with the index *bandIdx*. The process of deselection is controlled by the current configuration. Returns number of deselected observations;

int restoreOutliers(int bandIdx): performs restoration of previously deselected observations for a band with the index *bandIdx*; The process of restoration is controlled by the current configuration. Returns number of restored observations;

int doReWeighting(): evaluates the additional standard deviations to have a reduced $\chi^2 = 1$. The reweighting process is iterative, the number of iterations is limited by seven. The method returns a number of performed iterations;

In the following examples we assume that the session 12MAY10XU_V004 is successfully loaded. The following code makes initial set up and evaluates the ionosphere corrections. Then, it sets the group delays as observables, modifies the number of polynomial terms of clock model to three, sets up the estimated parameters (clocks, zenith delays and baseline length) and obtain a solution:

```
session.doStdSetup();
session.calcIono();
config.useDelayType = CFG.VD_GRP_DELAY;
session.setNumOfClockPolynoms4Stations(3);
parsDescript.setMode4Parameter(Parameters.Clocks,    Parameters.EstimateLocal);
parsDescript.setMode4Parameter(Parameters.Zenith,    Parameters.EstimateLocal);
parsDescript.setMode4Parameter(Parameters.Bl_Length, Parameters.EstimateLocal);
session.process();
```

In the following subsections we discuss the objects *Band*, *Station*, *Baseline*, *Source* and *Observation*. The first three objects are derived from a common ancestor which has the following properties:

8.6.1 The object «Band»

This object represents a band and its statistical information. The properties of *Band* are shown on Tab. 8.16. An example of accessing data for this object:

```
var bandKeys=Array();
print('Session number of bands : ' + session.bands.length);
for (var i=0; i<session.bands.length; i++)
{
    bandKeys[i] = session.bands[i].key;
```

Type	Property	Access	Meaning
String	key	Read only	a «canonical» name of the object;
String	name	Read only	same as key, but without trailing space chars;
int	numTotal	Read only	a number of total observations;
int	numUsable	Read only	a number of usable observations;
int	numProcessed	Read only	a number of analyzed observations;
Date	tFirst	Read only	the first epoch of observations;
Date	tLast	Read only	the last epoch of observations;
double	sigma2add	Read/Write	additional standard deviation for group delays to have a reduced $\chi^2 = 1$, applicable to band and baseline;
double	wrms	Read only	weighed root mean square of delays, in seconds;
double	chi2	Read only	non-reduced χ^2 for delays;
double	reducedChi2	Read only	reduced χ^2 for delays;
double	dof	Read only	degree of freedom for delays;

Table 8.15: Common properties of *Band*, *Station* and *Baseline* objects.

Type	Property	Access	Meaning
double	refFreq	Read only	a reference frequency of the band
int	numOfChannels	Read only	a designed number of channels
Date	tCreation	Read only	epoch of database creation
int	inputFileVersion	Read only	a version of a database
String	correlatorType	Read only	type of a correlator
double	groupDelaysAmbigSpacing	Read only	returns a typical ambiguity spacing for group delays
array of Stations	stations	Read only	an array of Objects that describe stations
array of Baselines	baselines	Read only	an array of Objects that describe baselines
array of Sources	sources	Read only	an array of Objects that describe sources

Table 8.16: Properties of *Band* objects.

```
    print('Session band[' + i + '] key            : ' + session.bands[i].key);
    print('Session band[' + i + '] name           : ' + session.bands[i].name);
    print('Session band[' + i + '] #Total         : ' + session.bands[i].numTotal);
    print('Session band[' + i + '] #Usable        : ' + session.bands[i].numUsable);
    print('Session band[' + i + '] #Used          : ' + session.bands[i].numProcessed);
    print('Session band[' + i + '] tFirst         : ' + session.bands[i].tFirst);
    print('Session band[' + i + '] tLast          : ' + session.bands[i].tLast);
    print('Session band[' + i + '] sig2add        : ' + session.bands[i].sigma2add*1.0e12 + ' (ps)');
    print('Session band[' + i + '] WRMS           : ' + session.bands[i].wrms*1.0e12 + ' (ps)');
    print('Session band[' + i + '] Chi2           : ' + session.bands[i].chi2);
    print('Session band[' + i + '] DoF            : ' + session.bands[i].dof);

    print('Session band[' + i + '] RefFreq        : ' + session.bands[i].refFreq);
    print('Session band[' + i + '] #Channels      : ' + session.bands[i].numOfChannels);
    print('Session band[' + i + '] tCreation      : ' + session.bands[i].tCreation);
    print('Session band[' + i + '] Version        : ' + session.bands[i].inputFileVersion);
    print('Session band[' + i + '] correlator type: ' + session.bands[i].correlatorType);

    print('++');
};
```

This script commands make the following output:

```
Session band[0] key            : X
Session band[0] name           : X
Session band[0] #Total         : 22
Session band[0] #Usable        : 19
Session band[0] #Used          : 17
```

```
Session band[0] tFirst         : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session band[0] tLast          : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session band[0] sig2add        : 0 (ps)
Session band[0] WRMS           : 17.2817678829019 (ps)
Session band[0] Chi2           : 6.7652418362446
Session band[0] DoF            : 9.0000000000016
Session band[0] RefFreq        : 8182.99
Session band[0] #Channels      : 8
Session band[0] tCreation      : Fri May 11 2012 15:45:24 GMT+0000 (UTC)
Session band[0] Version        : 4
Session band[0] correlator type:
++
Session band[1] key            : S
Session band[1] name           : S
Session band[1] #Total         : 22
Session band[1] #Usable        : 19
Session band[1] #Used          : 17
Session band[1] tFirst         : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session band[1] tLast          : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session band[1] sig2add        : 0 (ps)
Session band[1] WRMS           : 12.915293209587421 (ps)
Session band[1] Chi2           : 0.0526281339698778
Session band[1] DoF            : 16.889519141471364
Session band[1] RefFreq        : 2212.99
Session band[1] #Channels      : 6
Session band[1] tCreation      : Fri May 11 2012 15:28:07 GMT+0000 (UTC)
Session band[1] Version        : 2
Session band[1] correlator type:
++
```

As one can see, in this example the field correlator type is empty – the corresponding databases have the LCode «CORRTYPE», however no data provided there.

8.6.2 The object «Station»

The object *Station* represents a station that participates in a VLBI session, its statistical information and allows a user to change some particular options. The Tab. 8.17 lists its properties.
The *AuxObs* Object represents cable calibration corrections and meteorological parameters, and will be discussed later.

The property «flybyCableCalSource» is doing the same as the similar property of the object *config*, but works only for a specified station. The property has read only access, to alter a type of cable calibration corrections use *setFlybyCableCalSource* method:

bool setFlybyCableCalSource(NsScrPrx4TaskConfig::CableCalSource): set source of cable calibration corrections, returns true if success.

Check the properties *getHasCccFslg*, *getHasCccCdms* and *getHasCccPcmt* before calling *setFlybyCableCalSource*, e.g.:

```
var key='WETTZ13S';
var stn=session.lookUpStation(key);
if (stn != null)
{
    if (stn.getHasCccFslg)
        if (stn.setFlybyCableCalSource(CFG.CCS_PCMT))
```

Type	Property	Access	Meaning
double	cableCalSign	Read only	the sign that was applied to cable calibration corrections of the station during parsing station log file;
int	numOfScans	Read only	number of scans on the station;
int	numOfClockPolynoms	Read/Write	number of terms in clock polynomial model;
String	sId	Read only	returns two-char station ID;
boolean	isValid	Read/Write	**true** if station is in a solution, **false** if it should be deselected;
boolean	estimateCoords	Read/Write	if **true**, positions of this station should be estimated if a user decided to estimate station coordinates. This flag does not turn «on» or «off» estimation of station positions;
boolean	constrainCoords	Read/Write	if **true**, positions of this station should be used in equations of constraints.
boolean	referenceClocks	Read/Write	a flag specifies that a station is a reference clock station;
boolean	useCableCal	Read/Write	if **true**, the cable calibration corrections will be applied in a solution;
CFG.CableCalSource	flybyCableCalSource	Read only	Provides a source of origin of cable calibration corrections;
boolean	badMeteo	Read/Write	if **true**, meteorological parameters of the station are incorrect or suspicious, the software should use standard meteo parameters instead of what is provided in a database;
boolean	getHasCccFslg	Read only	**true** if the station has cable calibrations from a field system log file;
boolean	getHasCccCdms	Read only	**true** if the station has CDMS cable calibrations;
boolean	getHasCccPcmt	Read only	**true** if the station has proxy cable calibrations (PCMT);
bool	estimateTroposphere	Read only	if **true**, troposphere parameters of this station should be estimated if a user decided to estimate the troposphere parameters (zenith delay and its gradients). This flag does not turn «on» or «off» estimation of the troposphere parameters;
array of AuxObs	auxObs	Read only	an array of Objects that describe auxiliary data
double	latitude	Read only	latitude of a station
double	longitude	Read only	longitude of a station

Table 8.17: Properties of *Station* objects.

```
            print('stn = ' + stn.name + ': setting flybyCableCalSource to CFG.CCS_FSLG done');
        else
            print('stn = ' + stn.name + ': setting flybyCableCalSource to CFG.CCS_FSLG has failed');
    else
        print('stn = ' + stn.name + ': FS log file cable cal data are not available');

    print('stn = ' + stn.name + ': stn.flybyCableCalSource = ' + stn.flybyCableCalSource);
}
else
    print('Station ' + key + ' was not found');
```

The data from different sources of cable calibrations are collected by vgosDbProcLogs of version 0.6.5 and higher. The utility accumulates these data in a separate netCDF file. It does not interfere with the standard netCDF file for cable calibration corrections and designed mostly for testing purposes.

Here is an example of using properties of *Station*.

```
var stations=session.stations;
var stnByName=Object;

print('Session num of stations : ' + stations.length);
for (var i=0; i<stations.length; i++)
{
  stnByName[stations[i].name]=stations[i];
  print('Session stn[' + i + '] key          : \"' + stations[i].key + '\"');
```

```
  print('Session stn[' + i + '] name         : \"' + stations[i].name + '\"');
  print('Session stn[' + i + '] #Total       : ' + stations[i].numTotal);
  print('Session stn[' + i + '] #Usable      : ' + stations[i].numUsable);
  print('Session stn[' + i + '] #Used        : ' + stations[i].numProcessed);
  print('Session stn[' + i + '] tFirst       : ' + stations[i].tFirst);
  print('Session stn[' + i + '] tLast        : ' + stations[i].tLast);
  print('Session stn[' + i + '] sig2add      : ' + stations[i].sigma2add*1.0e12 + ' (ps)');
  print('Session stn[' + i + '] WRMS         : ' + stations[i].wrms*1.0e12 + ' (ps)');
  print('Session stn[' + i + '] Chi2         : ' + stations[i].chi2);
  print('Session stn[' + i + '] DoF          : ' + stations[i].dof);

  print('Session stn[' + i + '] #ClockTerms  : ' + stations[i].numOfClockPolynoms);
  print('Session stn[' + i + '] cableSign    : ' + stations[i].cableCalSign);
  print('Session stn[' + i + '] is valid     : ' + stations[i].isValid);
  print('Session stn[' + i + '] estimate coo : ' + stations[i].estimateCoords);
  print('Session stn[' + i + '] constrain coo: ' + stations[i].constrainCoords);
  print('Session stn[' + i + '] ref.clocks   : ' + stations[i].referenceClocks);
  print('Session stn[' + i + '] use cable cal: ' + stations[i].useCableCal);

  print('++');
};

print('Total number of observations at KOKEE = ' + stnByName['KOKEE'].numTotal);
```

The output will look like:

```
Session num of stations : 2
Session stn[0] key          : "KOKEE   "
Session stn[0] name         : "KOKEE"
Session stn[0] #Total       : 22
Session stn[0] #Usable      : 19
Session stn[0] #Used        : 17
Session stn[0] tFirst       : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session stn[0] tLast        : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session stn[0] sig2add      : 0 (ps)
Session stn[0] WRMS         : 17.2817678829019 (ps)
Session stn[0] Chi2         : 6.7652418362446
Session stn[0] DoF          : 9.0000000000016
Session stn[0] #ClockTerms  : 0
Session stn[0] cableSign    : -1
Session stn[0] is valid     : true
Session stn[0] estimate coo : true
Session stn[0] constrain coo: false
Session stn[0] ref.clocks   : true
Session stn[0] use cable cal: false
Session stn[0] # of AuxObs  : 22
++
Session stn[1] key          : "WETTZELL"
Session stn[1] name         : "WETTZELL"
Session stn[1] #Total       : 22
Session stn[1] #Usable      : 19
Session stn[1] #Used        : 17
Session stn[1] tFirst       : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session stn[1] tLast        : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session stn[1] sig2add      : 0 (ps)
Session stn[1] WRMS         : 17.2817678829019 (ps)
```

```
Session stn[1] Chi2         : 6.7652418362446
Session stn[1] DoF          : 9.0000000000016
Session stn[1] #ClockTerms  : 3
Session stn[1] cableSign    : 1
Session stn[1] is valid     : true
Session stn[1] estimate coo : false
Session stn[1] constrain coo: false
Session stn[1] ref.clocks   : false
Session stn[1] use cable cal: true
++
Total number of observations at KOKEE = 22
```

The object «AuxObs»

The Object *AuxObs* contains station dependent data and has the properties as it shown on Tab. 8.18.

Type	Property	Access	Meaning
Date	epoch	Read only	epoch of the measurements;
double	cableCalibration	Read only	cable calibration correction, sec;
double	atmPressure	Read only	atmospheric pressure, mbar;
double	atmTemperature	Read only	ambient temperature, C;
double	atmHumidity	Read only	relative humidity, 0.5=50%
Station	station	Read only	an owner;

Table 8.18: Properties of *AuxObs* objects.

An example to access these data:

```
var stnKokee = stnByName['KOKEE'];
for (var i=0; i<stnKokee.auxObs.length; i++)
{
    print('aux[' + i + '] ' + stnKokee.auxObs[i].epoch.toUTCString() + ' meteo= {' +
        stnKokee.auxObs[i].atmPressure.toFixed(2)  + '(mbar), ' +
        stnKokee.auxObs[i].atmTemperature.toFixed(2)  + '(C), ' +
        (stnKokee.auxObs[i].atmHumidity*100).toFixed(2)  + '(%)},  CC= ' +
        (stnKokee.auxObs[i].cableCalibration*1e12).toFixed(2) + '(ps)'  );
};
```

The output will look like:

```
aux[0] Thu, 10 May 2012 18:30:25 GMT meteo= {890.20(mbar), 12.70(C), 100.00(%)},  CC= -3.51(ps)
aux[1] Thu, 10 May 2012 18:33:13 GMT meteo= {890.24(mbar), 12.70(C), 100.00(%)},  CC= -3.88(ps)
aux[2] Thu, 10 May 2012 18:36:29 GMT meteo= {890.30(mbar), 12.73(C), 100.00(%)},  CC= -3.88(ps)
aux[3] Thu, 10 May 2012 18:38:26 GMT meteo= {890.27(mbar), 12.80(C), 100.00(%)},  CC= -5.91(ps)
aux[4] Thu, 10 May 2012 18:41:20 GMT meteo= {890.20(mbar), 12.80(C), 100.00(%)},  CC= -4.08(ps)
aux[5] Thu, 10 May 2012 18:44:52 GMT meteo= {890.20(mbar), 12.80(C), 100.00(%)},  CC= -5.18(ps)
aux[6] Thu, 10 May 2012 18:47:10 GMT meteo= {890.22(mbar), 12.80(C), 100.00(%)},  CC= -2.96(ps)
aux[7] Thu, 10 May 2012 18:49:13 GMT meteo= {890.30(mbar), 12.82(C), 100.00(%)},  CC= -1.86(ps)
aux[8] Thu, 10 May 2012 18:51:29 GMT meteo= {890.30(mbar), 12.90(C), 100.00(%)},  CC= -3.13(ps)
aux[9] Thu, 10 May 2012 18:53:24 GMT meteo= {890.30(mbar), 12.90(C), 100.00(%)},  CC= -2.01(ps)
aux[10] Thu, 10 May 2012 18:56:23 GMT meteo= {890.30(mbar), 12.90(C), 100.00(%)},  CC= -3.68(ps)
aux[11] Thu, 10 May 2012 18:59:59 GMT meteo= {890.36(mbar), 12.90(C), 100.00(%)},  CC= -4.23(ps)
aux[12] Thu, 10 May 2012 19:03:02 GMT meteo= {890.50(mbar), 12.92(C), 100.00(%)},  CC= -1.28(ps)
aux[13] Thu, 10 May 2012 19:05:19 GMT meteo= {890.50(mbar), 13.00(C), 100.00(%)},  CC= -2.01(ps)
aux[14] Thu, 10 May 2012 19:07:14 GMT meteo= {890.50(mbar), 13.00(C), 100.00(%)},  CC= -1.11(ps)
aux[15] Thu, 10 May 2012 19:08:57 GMT meteo= {890.47(mbar), 13.00(C), 100.00(%)},  CC= 2.04(ps)
```

```
aux[16] Thu, 10 May 2012 19:11:42 GMT meteo= {890.44(mbar), 13.00(C), 100.00(%)},  CC= 2.59(ps)
aux[17] Thu, 10 May 2012 19:15:21 GMT meteo= {890.47(mbar), 13.00(C), 100.00(%)},  CC= 8.34(ps)
aux[18] Thu, 10 May 2012 19:18:28 GMT meteo= {890.40(mbar), 13.02(C), 100.00(%)},  CC= 11.64(ps)
aux[19] Thu, 10 May 2012 19:20:59 GMT meteo= {890.40(mbar), 13.10(C), 100.00(%)},  CC= 11.49(ps)
aux[20] Thu, 10 May 2012 19:24:42 GMT meteo= {890.40(mbar), 13.10(C), 100.00(%)},  CC= 13.14(ps)
aux[21] Thu, 10 May 2012 19:27:49 GMT meteo= {890.40(mbar), 13.10(C), 100.00(%)},  CC= 11.84(ps)
```

8.6.3 The object «Baseline»

The object *Baseline* allows a user to access the statistical information and attributes of a particular baseline, the properties of the object are displayed on the Tab. 8.19.

Type	Property	Access	Meaning
double	length	Read only	a length of the baseline;
boolean	isValid	Read/Write	**true** if the baseline is in a solution, **false** if it should be deselected;
boolean	estimateClocks	Read/Write	if **true**, an additional baseline clock offset should be estimated if a user decided to estimate the baseline clock offsets. This flag does not turn «on» or «off» estimation of the offsets;

Table 8.19: Properties of *Baseline* objects.

An example for the same session:

```
var baselines=session.baselines;
print('Session num of baselines : ' + baselines.length);
for (var i=0; i<baselines.length; i++)
{
    print('Session bln[' + i + '] key    : \"' + baselines[i].key + '\"');
    print('Session bln[' + i + '] name   : \"' + baselines[i].name + '\"');
    print('Session bln[' + i + '] #Total : ' + baselines[i].numTotal);
    print('Session bln[' + i + '] #Usable: ' + baselines[i].numUsable);
    print('Session bln[' + i + '] #Used  : ' + baselines[i].numProcessed);
    print('Session bln[' + i + '] tFirst : ' + baselines[i].tFirst);
    print('Session bln[' + i + '] tLast  : ' + baselines[i].tLast);
    print('Session bln[' + i + '] sig2add: ' + baselines[i].sigma2add*1.0e12 + ' (ps)');
    print('Session bln[' + i + '] WRMS   : ' + baselines[i].wrms*1.0e12 + ' (ps)');
    print('Session bln[' + i + '] Chi2   : ' + baselines[i].chi2);
    print('Session bln[' + i + '] DoF    : ' + baselines[i].dof);
    print('Session bln[' + i + '] length : ' + baselines[i].length + '(m)');
    print('Session bln[' + i + '] isValid: ' + baselines[i].isValid);
    print('Session bln[' + i + '] EstClks: ' + baselines[i].estimateClocks);
    print('++');
};
```

The output will look like:

```
Session num of baselines : 1
Session bln[0] key    : "KOKEE   :WETTZELL"
Session bln[0] name   : "KOKEE:WETTZELL"
Session bln[0] #Total : 22
Session bln[0] #Usable: 19
Session bln[0] #Used  : 17
Session bln[0] tFirst : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session bln[0] tLast  : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session bln[0] sig2add: 17.98 (ps)
```

```
Session bln[0] WRMS   : 17.2817678829019 (ps)
Session bln[0] Chi2   : 6.7652418362446
Session bln[0] DoF    : 9.0000000000016
Session bln[0] length : 10357449.083383746(m)
Session bln[0] isValid: true
Session bln[0] EstClks: false
++
```

8.6.4 The object «Source»

On Tab. 8.20 the properties of the object *Source* are shown.

Type	Property	Access	Meaning
double	rightAscension	Read only	right ascension, rad;
double	declination	Declination, rad;	
boolean	isValid	Read/Write	**true** if the source is in a solution, **false** if it should be deselected;
boolean	estimateCoords	Read/Write	if **true**, coordinates of the source should be estimated if a user decided to estimate source coordinates. This flag does not turn «on» or «off» the estimation of source coordinates;
boolean	constrainCoords	Read/Write	if **true**, coordinates of this source should be used in equations of constraints.
boolean	applySsm	Read/Write	if **true**, a source structure model of the source should be applied.
String	aprioriComments	Read only	comments about a source from an external *a priori* file

Table 8.20: Properties of *Source* objects.

In addition, the following functions are implemented:

int numOfSrcStructPoints(): returns a number of components of a source structure model;

void addSrcStructPoint(double k, double b, double x, double y, boolean estK=false, boolean estB=false, boolean estR=
adds a component to the source structure model with relative positions x and y (in radians), ratio k ($0 < k < 1$), and difference of spectral indices b. The arguments estK, estB and estR control which parameters shoud be estimated (if Parameters.SrcSSM is set properly): the brightness ratio, the difference of spectral indices, the position. If last arguments are missed, the default value **false** will be used.

void clearSrcStructPoints(): removes all components of a model;

void setK_i(i, double v): sets brightness ratio of the ith component to value of v;

void setB_i(i, double v): sets difference of spectral indices of the ith component to value of v;

void setX_i(i, double v): sets x-coordinate of the ith component to value of v (in radians);

void setY_i(i, double v): sets y-coordinate of the ith component to value of v (in radians);

double getK_i(i): returns value of brightness ratio of the ith component;

double getB_i(i): returns value of difference of spectral indices of the ith component;

double getX_i(i): returns value of x-coordinate of the ith component;

double getY_i(i): returns value of y-coordinate of the ith component;

double getK_iSig(i): returns standard deviations of estimation of brightness ratio of the ith component;

double getB_iSig(i): returns standard deviations of estimation of difference of spectral indices of the ith component;

double getX_iSig(i): returns standard deviations of estimation of x-coordinate of the ith component;

double getY_iSig(i): returns standard deviations of estimation of y-coordinate of the ith component;

The use of *Source* object is similar to the previous objects:

```
var sources=session.sources;
print('Session num of sources: ' + sources.length);
for (var i=0; i<sources.length; i++)
{
    var src=sources[i];
    print('Session src[' + i + '] key    : \"' + src.key + '\"');
    print('Session src[' + i + '] name   : \"' + src.name + '\"');
    print('Session src[' + i + '] #Total : ' + src.numTotal);
    print('Session src[' + i + '] #Usable: ' + src.numUsable);
    print('Session src[' + i + '] #Used  : ' + src.numProcessed);
    print('Session src[' + i + '] tFirst : ' + src.tFirst);
    print('Session src[' + i + '] tLast  : ' + src.tLast);
    print('Session src[' + i + '] sig2add: ' + src.sigma2add*1.0e12 + ' (ps)');
    print('Session src[' + i + '] WRMS   : ' + src.wrms*1.0e12 + ' (ps)');
    print('Session src[' + i + '] Chi2   : ' + src.chi2);
    print('Session src[' + i + '] DoF    : ' + src.dof);
    print('Session src[' + i + '] RA     : ' + src.rightAscension + '(rad)');
    print('Session src[' + i + '] De     : ' + src.declination + '(rad)');
    print('Session src[' + i + '] isValid: ' + src.isValid);
    print('Session src[' + i + '] EstCoor: ' + src.estimateCoords);
    print('Session src[' + i + '] ConCoor: ' + src.constrainCoords);
    print('++');
};
```

The output for the first three sources would be:

```
Session num of sources: 8
Session src[0] key    : "0059+581"
Session src[0] name   : "0059+581"
Session src[0] #Total : 4
Session src[0] #Usable: 4
Session src[0] #Used  : 4
Session src[0] tFirst : Thu May 10 2012 18:36:29 GMT+0000 (UTC)
Session src[0] tLast  : Thu May 10 2012 19:27:49 GMT+0000 (UTC)
Session src[0] sig2add: 0 (ps)
Session src[0] WRMS   : 6.468445427175654 (ps)
Session src[0] Chi2   : 0.435196539219441
Session src[0] DoF    : 1.4692610127891128
Session src[0] RA     : 0.27385396839018517(rad)
Session src[0] De     : 1.0193262750705432(rad)
Session src[0] isValid: true
Session src[0] EstCoor: true
Session src[0] ConCoor: false
++
Session src[1] key    : "0552+398"
Session src[1] name   : "0552+398"
Session src[1] #Total : 3
Session src[1] #Usable: 3
Session src[1] #Used  : 3
Session src[1] tFirst : Thu May 10 2012 18:49:13 GMT+0000 (UTC)
Session src[1] tLast  : Thu May 10 2012 19:18:28 GMT+0000 (UTC)
Session src[1] sig2add: 0 (ps)
Session src[1] WRMS   : 7.817527397115135 (ps)
Session src[1] Chi2   : 0.24670886152400762
Session src[1] DoF    : 1.3944546913275808
Session src[1] RA     : 1.5512199587587385(rad)
```

```
Session src[1] De     : 0.6948794009400607(rad)
Session src[1] isValid: true
Session src[1] EstCoor: true
Session src[1] ConCoor: false
++
Session src[2] key    : "0556+238"
Session src[2] name   : "0556+238"
Session src[2] #Total : 1
Session src[2] #Usable: 1
Session src[2] #Used  : 0
Session src[2] tFirst : Fri Jan 01 2100 00:00:00 GMT+0000 (UTC)
Session src[2] tLast  : Fri Oct 04 1957 00:00:00 GMT+0000 (UTC)
Session src[2] sig2add: 0 (ps)
Session src[2] WRMS   : 0 (ps)
Session src[2] Chi2   : 0
Session src[2] DoF    : 1
Session src[2] RA     : 1.5687625188339909(rad)
Session src[2] De     : 0.41710424737671953(rad)
Session src[2] isValid: true
Session src[2] EstCoor: true
Session src[2] ConCoor: false
++
```

8.6.5 The object «Observation»

On Tab. 8.21 the properties of the object *Observation* are shown. The object allows to access the statistical information for an observation and modify its editing data. This is a complex object, it contains data that depend on band and type of delay. If a session has more than one band, not all bands can be present in the object *Observation*.

Type	Property	Access	Meaning
String	key	Read only	a key that represent the observation;
String	scanName	Read only	name of the scan;
Date	epoch	Read only	reference epoch of the observation;
boolean	isValid	Read/Write	**true** if the observation is ok to be in a solution, **false** if it should be deselected. If *isValid* is **true** it is not necessary that the observation will be in a solution – other reasons could prevent that, like low quality factor, deselected baseline, etc.;
boolean	isProcessed	Read only	**true** if the observation was processed in the last solution;
int	numOfBands	Read only	a number of available bands for the observation;
double	gmst	Read only	returns Greenwich Mean Sidereal Time in radians;
Station	station_1	Read only	the reference station;
Station	station_2	Read only	the remote station;
Baseline	baseline	Read only	the baseline;
Source	source	Read only	the source.

Table 8.21: Properties of *Source* objects.

The access to band and delay type dependent data are made with methods. The following functions are implemented currently:

int qualityFactor(String bandKey): returns a quality factor for the observation on the band *bandKey*, if the observation does not exist on this band, returns -1;

double correlationCoeff(String bandKey): returns a correlation coefficient for the observation on the band *bandKey*, if the observation does not exist on this band, returns -1.0;

double snr(String bandKey): returns signal to noise ratio for the observation on the band *bandKey*, if the observation does not exist on this band, returns -1.0;

int numOfChannels(String bandKey): returns number of channels for the observation on the band *bandKey*, if the observation does not exist on this band, returns -1;

boolean isUsable(String bandKey): returns **true** if the observation on the band *bandKey* is potentially usable (i.e., has acceptable quality code, has more than one channel and the stations, the source and the baseline are not deselected; the flag *isValid* can be **true** or **false**), if the observation does not exist on this band, returns **false**;

double delayValue(String bandKey, CFG.VlbiDelayType delayType): returns value of a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double delayValueGeoc(String bandKey, CFG.VlbiDelayType delayType): returns value of a delay of the type *delayType* on the band *bandKey* calculated at the geocenter, if the observation does not exist on this band, returns 0.0;

double delayStdDev(String bandKey, CFG.VlbiDelayType delayType): returns value of standard deviations of a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns -1.0;

double delayResidual(String bandKey, CFG.VlbiDelayType delayType): returns value of the residual for a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double delayResidualNorm(String bandKey, CFG.VlbiDelayType delayType): returns value of the normalized residual for a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double delayAmbiguitySpacing(String bandKey, CFG.VlbiDelayType delayType): returns ambiguity spacings for a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns -1.0;

int delayNumOfAmbiguities(String bandKey, CFG.VlbiDelayType delayType): returns multiplier of ambiguities for a delay of the type *delayType* on the band *bandKey*, if the observation does not exist on this band, returns 0;

double rateValue(String bandKey): returns value of the delay rate on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double rateStdDev(String bandKey): returns value of standard deviations of the delay rate on the band *bandKey*, if the observation does not exist on this band, returns -1.0;

double rateResidual(String bandKey): returns value of the residual for the delay rate on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double rateResidualNorm(String bandKey): returns value of the normalized residual for the delay rate on the band *bandKey*, if the observation does not exist on this band, returns 0.0;

double delaySourceStructure(String bandKey): returns value of the source structure effect (if it has been applied).

An example of use this object in a script (see subsection 8.6.1 for definition of the variable *bandKeys*):

```
var observations=session.observations;
print('Number of observations: ' + observations.length);
for (var i=0; i<4/*observations.length*/; i++)
{
    print('obs[' + i + '] key    : ' + observations[i].key);
    print('obs[' + i + '] Scan   : ' + observations[i].scanName);
    print('obs[' + i + '] Epoch  : ' + observations[i].epoch.toUTCString());
    print('obs[' + i + '] isValid: ' + observations[i].isValid);
    print('obs[' + i + '] isProcd: ' + observations[i].isProcessed);
    print('obs[' + i + '] #ofBnds: ' + observations[i].numOfBands);
    print('obs[' + i + '] Stn_1  : ' + observations[i].station_1.name);
    print('obs[' + i + '] Stn_2  : ' + observations[i].station_2.name);
    print('obs[' + i + '] Bln    : ' + observations[i].baseline.name);
    print('obs[' + i + '] Src    : ' + observations[i].source.name);
    for (var j=0; j<bandKeys.length; j++)
    {
        var key=bandKeys[j];
```

```
        print('     band[' + j + '] key   : "' + key + '"');
        print('     band[' + j + '] QF    :  ' + observations[i].qualityFactor(key));
        print('     band[' + j + '] SNR   :  ' + observations[i].snr(key));
        print('     band[' + j + '] #Chann:  ' + observations[i].numOfChannels(key));
        print('     band[' + j + '] usable:  ' + observations[i].isUsable(key));

        print('     band[' + j + '] SB delay_residual        :  ' +
            observations[i].delay_residual(key, CFG.VD_SB_DELAY)*1.0e12 + ' (ps)');
        print('     band[' + j + '] SB delay_residualNorm    :  ' +
            observations[i].delay_residualNorm(key, CFG.VD_SB_DELAY));
        print('     band[' + j + '] SB delay_ambiguitySpacing:  ' +
            observations[i].delay_ambiguitySpacing(key, CFG.VD_SB_DELAY));
        print('     band[' + j + '] SB delay_numOfAmbiguities:  ' +
            observations[i].delay_numOfAmbiguities(key, CFG.VD_SB_DELAY));

        print('     band[' + j + '] GR delay_residual        :  ' +
            observations[i].delay_residual(key, CFG.VD_GRP_DELAY)*1.0e12 + ' (ps)');
        print('     band[' + j + '] GR delay_residualNorm    :  ' +
            observations[i].delay_residualNorm(key, CFG.VD_GRP_DELAY));
        print('     band[' + j + '] GR delay_ambiguitySpacing:  ' +
            observations[i].delay_ambiguitySpacing(key, CFG.VD_GRP_DELAY)*1.0e9 + ' (ns)');
        print('     band[' + j + '] GR delay_numOfAmbiguities:  ' +
            observations[i].delay_numOfAmbiguities(key, CFG.VD_GRP_DELAY));

        print('     band[' + j + '] PH delay_residual        :  ' +
            observations[i].delay_residual(key, CFG.VD_PHS_DELAY)*1.0e12 + ' (ps)');
        print('     band[' + j + '] PH delay_residualNorm    :  ' +
            observations[i].delay_residualNorm(key, CFG.VD_PHS_DELAY));
        print('     band[' + j + '] PH delay_ambiguitySpacing:  ' +
            observations[i].delay_ambiguitySpacing(key, CFG.VD_PHS_DELAY)*1.0e9 + ' (ns)');
        print('     band[' + j + '] PH delay_numOfAmbiguities:  ' +
            observations[i].delay_numOfAmbiguities(key, CFG.VD_PHS_DELAY));

        print('     band[' + j + '] rate_residual            :  ' +
            observations[i].rate_residual(key)*1.0e12 + ' (ps/s)');
        print('     band[' + j + '] rate_residualNorm        :  ' +
            observations[i].rate_residualNorm(key));
    };
    print('++');
};
```

The output of such script commands is:

```
Number of observations: 22
obs[0] key    : 056057:66625.000000-KOKEE   :WETTZELL@1803+784
obs[0] Scan   : 131-1830
obs[0] Epoch  : Thu, 10 May 2012 18:30:25 GMT
obs[0] isValid: true
obs[0] isProcd: false
obs[0] #ofBnds: 2
obs[0] Stn_1  : KOKEE
obs[0] Stn_2  : WETTZELL
obs[0] Bln    : KOKEE:WETTZELL
obs[0] Src    : 1803+784
     band[0] key   : "X"
     band[0] QF    :  0
```

```
     band[0] SNR   :  5.226466655731201
     band[0] #Chann:  8
     band[0] usable:  false
     band[0] SB delay_residual        :  -77101.6270768163 (ps)
     band[0] SB delay_residualNorm    :  0
     band[0] SB delay_ambiguitySpacing:  0
     band[0] SB delay_numOfAmbiguities:  0
     band[0] GR delay_residual        :  6727.071629084957 (ps)
     band[0] GR delay_residualNorm    :  77.15231240080058
     band[0] GR delay_ambiguitySpacing:  50.00000074505806 (ns)
     band[0] GR delay_numOfAmbiguities:  0
     band[0] PH delay_residual        :  3400.7440136160444 (ps)
     band[0] PH delay_residualNorm    :  0
     band[0] PH delay_ambiguitySpacing:  0.12220471979068775 (ns)
     band[0] PH delay_numOfAmbiguities:  0
     band[0] rate_residual            :  -6.381405499851667 (ps/s)
     band[0] rate_residualNorm        :  -8.3056343106481
     band[1] key   : "S"
     band[1] QF    :  0
     band[1] SNR   :  5.031310081481934
     band[1] #Chann:  6
     band[1] usable:  false
     band[1] SB delay_residual        :  -77101.6270768163 (ps)
     band[1] SB delay_residualNorm    :  0
     band[1] SB delay_ambiguitySpacing:  0
     band[1] SB delay_numOfAmbiguities:  0
     band[1] GR delay_residual        :  6727.071629084955 (ps)
     band[1] GR delay_residualNorm    :  71.18153710199417
     band[1] GR delay_ambiguitySpacing:  200.00000298023224 (ns)
     band[1] GR delay_numOfAmbiguities:  0
     band[1] PH delay_residual        :  -40673.30872801258 (ps)
     band[1] PH delay_residualNorm    :  0
     band[1] PH delay_ambiguitySpacing:  0.45187732434398714 (ns)
     band[1] PH delay_numOfAmbiguities:  0
     band[1] rate_residual            :  -6.381405499851667 (ps/s)
     band[1] rate_residualNorm        :  -2.762912372499939
++
obs[1] key    : 056057:66793.500000-KOKEE   :WETTZELL@DA426
obs[1] Scan   : 131-1831
obs[1] Epoch  : Thu, 10 May 2012 18:33:13 GMT
obs[1] isValid: false
obs[1] isProcd: false
obs[1] #ofBnds: 2
obs[1] Stn_1  : KOKEE
obs[1] Stn_2  : WETTZELL
obs[1] Bln    : KOKEE:WETTZELL
obs[1] Src    : DA426
     band[0] key   : "X"
     band[0] QF    :  9
     band[0] SNR   :  13.297061920166016
     band[0] #Chann:  8
     band[0] usable:  true
     band[0] SB delay_residual        :  -34066.25062244681 (ps)
     band[0] SB delay_residualNorm    :  0
     band[0] SB delay_ambiguitySpacing:  0
```

```
     band[0] SB delay_numOfAmbiguities:  0
     band[0] GR delay_residual        :  -183.1095294019572 (ps)
     band[0] GR delay_residualNorm    :  -5.249131073406312
     band[0] GR delay_ambiguitySpacing:  50.00000074505806 (ns)
     band[0] GR delay_numOfAmbiguities:  0
     band[0] PH delay_residual        :  277.664214584888 (ps)
     band[0] PH delay_residualNorm    :  0
     band[0] PH delay_ambiguitySpacing:  0.12220471979068775 (ns)
     band[0] PH delay_numOfAmbiguities:  0
     band[0] rate_residual            :  0.5900324167213904 (ps/s)
     band[0] rate_residualNorm        :  0.9157038262848808
     band[1] key   : "S"
     band[1] QF    :  9
     band[1] SNR   :  16.091747283935547
     band[1] #Chann:  6
     band[1] usable:  true
     band[1] SB delay_residual        :  -34066.25062244681 (ps)
     band[1] SB delay_residualNorm    :  0
     band[1] SB delay_ambiguitySpacing:  0
     band[1] SB delay_numOfAmbiguities:  0
     band[1] GR delay_residual        :  -183.1095294019579 (ps)
     band[1] GR delay_residualNorm    :  -5.910117229529999
     band[1] GR delay_ambiguitySpacing:  200.00000298023224 (ns)
     band[1] GR delay_numOfAmbiguities:  0
     band[1] PH delay_residual        :  7128.312369242522 (ps)
     band[1] PH delay_residualNorm    :  0
     band[1] PH delay_ambiguitySpacing:  0.45187732434398714 (ns)
     band[1] PH delay_numOfAmbiguities:  0
     band[1] rate_residual            :  0.5900324167213904 (ps/s)
     band[1] rate_residualNorm        :  0.9305854845553957
++
obs[2] key    : 056057:66989.000000-KOKEE   :WETTZELL@0059+581
obs[2] Scan   : 131-1835
obs[2] Epoch  : Thu, 10 May 2012 18:36:29 GMT
obs[2] isValid: true
obs[2] isProcd: true
obs[2] #ofBnds: 2
obs[2] Stn_1  : KOKEE
obs[2] Stn_2  : WETTZELL
obs[2] Bln    : KOKEE:WETTZELL
obs[2] Src    : 0059+581
     band[0] key   : "X"
     band[0] QF    :  9
     band[0] SNR   :  115.29768371582031
     band[0] #Chann:  8
     band[0] usable:  true
     band[0] SB delay_residual        :  -32824.42245431099 (ps)
     band[0] SB delay_residualNorm    :  0
     band[0] SB delay_ambiguitySpacing:  0
     band[0] SB delay_numOfAmbiguities:  0
     band[0] GR delay_residual        :  4.653915341358772 (ps)
     band[0] GR delay_residualNorm    :  0.3670455669661493
     band[0] GR delay_ambiguitySpacing:  50.00000074505806 (ns)
     band[0] GR delay_numOfAmbiguities:  0
     band[0] PH delay_residual        :  1181.6100078639383 (ps)
```

```
     band[0] PH delay_residualNorm    :  0
     band[0] PH delay_ambiguitySpacing:  0.12220471979068775 (ns)
     band[0] PH delay_numOfAmbiguities:  0
     band[0] rate_residual            :  0.17664172145018558 (ps/s)
     band[0] rate_residualNorm        :  0.2743711079130166
     band[1] key   : "S"
     band[1] QF    :  9
     band[1] SNR   :  53.394752502441406
     band[1] #Chann:  6
     band[1] usable:  true
     band[1] SB delay_residual        :  -32824.42245431099 (ps)
     band[1] SB delay_residualNorm    :  0
     band[1] SB delay_ambiguitySpacing:  0
     band[1] SB delay_numOfAmbiguities:  0
     band[1] GR delay_residual        :  4.653915341361047 (ps)
     band[1] GR delay_residualNorm    :  0.5560407163248116
     band[1] GR delay_ambiguitySpacing:  200.00000298023224 (ns)
     band[1] GR delay_numOfAmbiguities:  0
     band[1] PH delay_residual        :  17451.212584490735 (ps)
     band[1] PH delay_residualNorm    :  0
     band[1] PH delay_ambiguitySpacing:  0.45187732434398714 (ns)
     band[1] PH delay_numOfAmbiguities:  0
     band[1] rate_residual            :  0.17664172145018553 (ps/s)
     band[1] rate_residualNorm        :  0.2779574963913654
++
obs[3] key    : 056057:67106.500000-KOKEE   :WETTZELL@3C418
obs[3] Scan   : 131-1837
obs[3] Epoch  : Thu, 10 May 2012 18:38:26 GMT
obs[3] isValid: true
obs[3] isProcd: true
obs[3] #ofBnds: 2
obs[3] Stn_1  : KOKEE
obs[3] Stn_2  : WETTZELL
obs[3] Bln    : KOKEE:WETTZELL
obs[3] Src    : 3C418
     band[0] key   : "X"
     band[0] QF    :  9
     band[0] SNR   :  39.00614929199219
     band[0] #Chann:  8
     band[0] usable:  true
     band[0] SB delay_residual        :  -36703.61749143739 (ps)
     band[0] SB delay_residualNorm    :  0
     band[0] SB delay_ambiguitySpacing:  0
     band[0] SB delay_numOfAmbiguities:  0
     band[0] GR delay_residual        :  25.062730303683104 (ps)
     band[0] GR delay_residualNorm    :  0.9088012160598974
     band[0] GR delay_ambiguitySpacing:  50.00000074505806 (ns)
     band[0] GR delay_numOfAmbiguities:  0
     band[0] PH delay_residual        :  1243.4952193442662 (ps)
     band[0] PH delay_residualNorm    :  0
     band[0] PH delay_ambiguitySpacing:  0.12220471979068775 (ns)
     band[0] PH delay_numOfAmbiguities:  0
     band[0] rate_residual            :  0.025152838979971313 (ps/s)
     band[0] rate_residualNorm        :  0.03878200018615596
     band[1] key   : "S"
```

```
    band[1] QF    :  9
    band[1] SNR   :  7.94821834564209
    band[1] #Chann:  6
    band[1] usable:  true
    band[1] SB delay_residual        :  -36703.61749143739 (ps)
    band[1] SB delay_residualNorm    :  0
    band[1] SB delay_ambiguitySpacing:  0
    band[1] SB delay_numOfAmbiguities:  0
    band[1] GR delay_residual        :  25.06273030368269 (ps)
    band[1] GR delay_residualNorm    :  0.4574713346056261
    band[1] GR delay_ambiguitySpacing:  200.00000298023224 (ns)
    band[1] GR delay_numOfAmbiguities:  0
    band[1] PH delay_residual        :  17906.143770210678 (ps)
    band[1] PH delay_residualNorm    :  0
    band[1] PH delay_ambiguitySpacing:  0.45187732434398714 (ns)
    band[1] PH delay_numOfAmbiguities:  0
    band[1] rate_residual            :  0.02515283897997139 (ps/s)
    band[1] rate_residualNorm        :  0.018590603245821645
++
```

8.7 Passing arguments to a script

When a user runs a script, νSolve pass the optional (i.e., others than start with «–» char and parsed by νSolve) command line arguments to the script. In scripts these command line arguments visible as an object *args* that is an array of *String*. As an example of using arguments, let us consider a script that uses arguments:

```
function main()
{
    const       selfName = 'export2ngs';
    // check arguments:
    if (!args.length)
    {
        print('\nscript ' + selfName + ' usage:\n');
        print(selfName + ' input [input type]');
        print('where arguments:');
        print('   input      -- a database name (with or without version part) or a wrapper file name');
        print('   input type -- either \'DBH\' (default) or \'VDB\', optional.');
        return;
    };

    handler.fileName  = args[0];
    handler.inputType = 'DBH';
    if (args.length > 1)
        handler.inputType = args[1];
    // check:
    if (handler.inputType == '---')
    {
        print(selfName + ': ERROR: wrong input type.');
        return;
    };
    print(selfName + ': Session name = ' + handler.fileName);
    print(selfName + ': input type   = ' + handler.inputType);
    handler.importSession();
    if (session.isOk)
    {
```

```
        print(selfName + ': Session loaded.');
        handler.exportDataToNgs();
        print(selfName + ': Session exported as an NGS file.');
    }
    else
        print(selfName + ': ERROR: reading the file ' + handler.fileName + ' as ' +
            handler.inputType + ' type has failed.');
};
// end of main body


main();
```

The script performs a simple action: reads a VLBI session that is provided by a user and exports it into an ASCII file in NGS format. Also, a user optionally can specify a type of input – read data from databases or use the vgosDb format. Since ECMAScript does not have program structuring – all commands are executed as they appear in a file, we put everything in a function *main()* and the script consists of one command that is calling this function.

First, it checks for a size of the array *args* and if it is zero, prints info how to use the script and exits. Then, it uses the first argument as a file name of input VLBI session and, if the number of the arguments more than one, uses the second argument as the type of input data. The input type can be either string «DBH» or «VDB», trying to assign anything else to the property *inputType* of the object *handler* will reset it to the value «---», which means "unknown". The script checks for the result of the assignment and, if the second argument was not recognized, complains and exits. If the result of checking is satisfying, the script read a VLBI session and, if it was successful, exports data into NGS format.

This script is given here for education purposes. It also can be found in *scripts* directory of the current distribution under the name «export2ngs.js».

Using this feature makes easy to organize data processing in a batch mode. For example, if a user created an ASCII file under the name *sessionList* and put there the following strings:

```
18JAN02XU
18JAN03XU
18JAN04XU
18JAN05XU
18JAN08XU
18JAN10XU
```

Then, results of executing a shell script

```
#!/bin/bash

list=`cat sessionList`

for i in $list
do
    nuSolve -t export2ngs.js $i
done
```

will be six NGS files for the sessions from the list. The files will be saved in a directory specified in the Preferences, see subsection 4.1.1.

8.8 Control of the log output

During its work, various parts of νSolve generate messages. The messages have two attributes: *log level* and *log facility*. The level of a message specifies how severe the message is, it could vary from «error» to «<debug». The facility of a message describes to which module or sub-module it belongs, e.g., graphical user interface, input/output operations, etc.. All generated messages come through *logger* that filters them and display eligible messages. A user can configure the logger which log level and facility it should accept and ignore, see the subsection *4.1.4 Configuration of logging subsystem.*

By default, set up of the logging subsystem of the software is the same as it is in interactive mode – νSolve reads the configuration before executing a script. To override behavior of the logging system an object *logger* is available in scripts. Properties of this object are shown on Tab. 8.22.

Type	Property	Access	Meaning
String	fileName	Read/Write	a file name where the log messages should be saved;
String	dirName	Read/Write	a directory where the file fileName is expected;
boolean	have2store	Read/Write	if **true**, log messages will be stored in the file, otherwise – discarded;
boolean	isMute	Read/Write	if **true**, the messages will be send to the standard error stream, otherwise – muted;

Table 8.22: Properties of *logger* objects.

Types for log level and log facility are provided by the metaobject *Log*, Tab. 8.23 and Tab. 8.24 list these types.

Values	Meaning
Err	error message
Wrn	warning message
Inf	routine message
Dbg	debug message

Table 8.23: Enumerated type *log level* of metaobject **Log**.

The object *logger* has the following methods:

write(LogLevel lvl, int facilities, String message): put a message *message* of log level *lvl* and facility(ies) *facilities* into a log system.

addLogFacility(LogLevel lvl, int facilities): sets a facilities *facilities* of a level *lvl* to be accepted by the log system;

delLogFacility(LogLevel lvl, int facilities): sets a facilities *facilities* of a level *lvl* to be ignored by the log system;

boolean isEligible(LogLevel lvl, int facilities): returns **true** if a message of the log level *lvl* and facilities *facilities* is acceptable by the log system;

rmLogFile(): if a log file exists, deletes it;

The argument *facilities* above can be either a value from Tab. 8.24 or a combination of them. For example:

```
logger.write(Log.Dbg, Log.Config | Log.Gui, 'A user pressed a button');
```

An example of use this object in a script:

```
print('logger file name : ' + logger.fileName);
print('logger dir  name : ' + logger.dirName);
print('logger have2store: ' + logger.have2store);

logger.have2store = false;
logger.write(Log.Inf, Log.Run, "a test message");

print('debug level for "Preproc" facility (init): ' + logger.isEligible(Log.Dbg, Log.Preproc));

logger.addLogFacility(Log.Dbg, Log.Preproc);
print('debug level for Preproc facility (enabled): ' + logger.isEligible(Log.Dbg, Log.Preproc));

logger.write(Log.Dbg, Log.Preproc, "testing enable.");

logger.delLogFacility(Log.Dbg, Log.Preproc);
print('debug level for Preproc facility (disabled): ' + logger.isEligible(Log.Dbg, Log.Preproc));
```

Values	Meaning
IoBin	binary input/output operations
IoTxt	input/output operations for text files
IoNcdf	netCDF IO
IoDbh	database handler access
Io	a combination of *IoBin*, *IoTxt*, *IoNcdf* and *IoDbh*
Matrix	general vector and matrix operations
Matrix3d	3-d vector and matrix operations
Interp	interpolations
Math	a combination of *Matrix*, *Matrix3d* and *Interp*
Obs	data manipulations with an observation
Station	data manipulations with a station
Source	data manipulations with a source
Session	data manipulations with a session
Data	a combination of *Obs*, *Station*, *Source* and *Session*
RefFrame	calculations of reference frames transformations
Time	time scale conversion
Iono	evaluation of ionosphere corrections
Refraction	calculation of troposphere effects
Delay	calculation of theoretical delay
Rate	calculation of theoretical rate
FlyBy	applying «fly by» to the theoretical values
Displacement	evaluation of site displacements
Geo	a combination of *RefFrame*, *Time*, *Iono*, *Refraction*, *Delay*, *Rate*, *FlyBy* and *Displacement*
Estimator	estimator
Pwl	piece-wise continuous parameters
Stoch	stochastic parameters
Config	software configuration
Gui	graphical user interface
Report	report generator
Run	obtaining a solution
Preproc	preliminary processing
All	a combination of *Io*, *Math*, *Data*, *Geo*, *Estimator*, *Pwl*, *Stoch*, *Config*, *Gui*, *Report*, *Run* and *Preproc*

Table 8.24: Enumerated type *log facility* of metaobject **Log**.

```
logger.write(Log.Dbg, Log.Preproc, "testing disable.");


print('debug level for Log.Config facility: ' + logger.isEligible(Log.Dbg, Log.Config));
print('debug level for Log.Gui facility   : ' + logger.isEligible(Log.Dbg, Log.Gui));
print('debug level for (Log.Config | Log.Gui) facilities: ' + logger.isEligible(Log.Dbg, Log.Config | Log.Gui));

logger.write(Log.Dbg, Log.Config | Log.Gui, 'A user pressed a button');
```

These script commands will generate output:

```
logger file name : nuSolve.log
logger dir  name : /home/slb/nuSolve
logger have2store: true
15:44:01 a test message
debug level for "Preproc" facility (init): true
debug level for Preproc facility (enabled): true
15:44:01 testing enable.
debug level for Preproc facility (disabled): false
debug level for Log.Config facility: true
debug level for Log.Gui facility   : false
```

```
debug level for (Log.Config | Log.Gui) facilities: true
15:44:01 A user pressed a button
```

Using this interface we can modify the script «export2ngs.js» mentioned above. Suppose, we want to keep for each session a log in a separate file, also, override the log files if they already exists from previous execution of the script. Also, we do not want to log any debug messages and have output to the screen. Then, the script would look like:

```
function main()
{
    const       selfName = 'export2ngs';
    // check arguments:
    if (!args.length)
    {
        print('\nscript ' + selfName + ' usage:\n');
        print(selfName + ' input [input type]');
        print('where arguments:');
        print('   input      -- a database name (with or without version part) or a wrapper file name');
        print('   input type -- either \'DBH\' (default) or \'VDB\', optional.');
        return;
    };

    handler.fileName  = args[0];
    handler.inputType = 'DBH';
    if (args.length > 1)
        handler.inputType = args[1];
    // check:
    if (handler.inputType == '---')
    {
        print(selfName + ': ERROR: wrong input type.');
        return;
    };
    print(selfName + ': Session name = ' + handler.fileName);
    print(selfName + ': input type   = ' + handler.inputType);

    // set up logging:
    logger.fileName = selfName + '.' + handler.fileName + '.log';
    logger.have2store = true;
    // log all error messages:
    logger.addLogFacility(Log.Err, Log.All);
    // log all warning messages:
    logger.addLogFacility(Log.Wrn, Log.All);
    // log all information messages:
    logger.addLogFacility(Log.Inf, Log.All);
    // skip all debug messages:
    logger.delLogFacility(Log.Dbg, Log.All);
    // delete the file if it exists:
    logger.rmLogFile();
    logger.isMute = true;

    logger.write(Log.Inf, Log.Preproc, selfName + ': Starting processing ' + handler.fileName + ' file');

    handler.importSession();
    if (session.isOk)
    {
        print(selfName + ': Session loaded.');
        handler.exportDataToNgs();
```

```
        print(selfName + ': Session exported as an NGS file.');
    }
    else
        print(selfName + ': ERROR: reading the file ' + handler.fileName + ' as ' +
            handler.inputType + ' type has failed.');
};
// end of main body


main();
```

Chapter 9

Selected practical issues of using νSolve in a script mode

9.1 Converting data format of a VLBI session

Using the script capabilities of νSolve it is easy to convert data format of a VLBI session. As examples, the software distribution contains two scripts, `export2ngs.js` and `vgosDxConvertor.js`. The first script exports some data from vgosDb, DBH or vgosDa files into NGS format. The second script converts a VLBI session from vgosDb to vgosDa format or back. Invocation of the scripts without arguments will print its usage.

The files are available in `scripts` directory of the distribution and are installed in `[PREFIX]/share/nusolve/scripts` when a user execute `make install` command (see *Chapter 2 Installation*).

Starting version 0.7.1 there is no needs to provide a path to script files that come with the distribution. To export VLBI database 17DEC03XB in the NGS format a user can type (assuming the database is in proper place):

```
> nuSolve -t export2ngs.js 17DEC03XB
```

And to convert a VLBI session that is in vgosDa format in a file `20191209_a_v002.env.vda` into the vgosDb format, type:

```
> nuSolve -t vgosDxConvertor.js a2b 20191209_a_v002.env.vda
```

In both cases the software assumes that the input files are in predefined directories, see subsection *4.1.1 Specifying directories, external files.* A user can provide an alternative path to the input files, i.e.:

```
> nuSolve -t vgosDxConvertor.js b2a /tmp/16APR02XA
```

To change a path for output, the scripts should be edited by a user.

In addition to the ECMAScript `vgosDxConvertor.js` a bash wrapper `vgosDxConvertor` is provided by the distribution. This script is installed in the same directory as nuSolve, so a user can perform conversion between vgosDa and vgosDb formats with minimum typing:

```
> vgosDxConvertor db2da ~/500/vgosDb/2020/20APR01XA ~/500/vgosDa/
```

or

```
> vgosDxConvertor da2db ~/500/vgosDa/20APR01XU.vda ~/tmp/20APR01XU.tgz
```

or

```
> vgosDxConvertor db2da ~/Downloads/20APR01XA.tgz ~/tmp/vda/20APR01XA.vda
```

Note, in contrast to previous scripts, this script, `vgosDxConvertor`, does not use user set up, the input and output path have to be provided explicitly by a user.

Chapter 10

Concluding remark

Currently, this document is in the developmental stage, and it is likely to be changed frequently. Check for new versions at the web site:

`https://sourceforge.net/projects/nusolve/`

If you have questions or suggestions that will improve the software or the User Guide, please e-mail us at:

`<mailto:sergei.bolotin@nasa.gov>`

Happy solving!

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