Single Session Analysis using VieVS

1 Description

This exercise will give a short introduction to the possibilities for analyzing VLBI observations using the Vienna VLBI and Satellite Software (VieVS). In the following, the IVS session t2p180 (20260224-t2p180) will be analyzed. To get a general idea about the session, you can go to the IVS homepage https://ivscc.gsfc.nasa.gov/sessions/ where information about sessions run by the IVS is stored.

2 Before you start

- download VieVS from https://github.com/TUW-VieVS/VLBI
- download the session from https://tucloud.tuwien.ac.at/index.php/apps/files/files/1206540258?dir=/Shared/VieVS%20Days%202026/SS and save it in VieVS/VLBI/DATA/vgosDB/<yearofsession>.

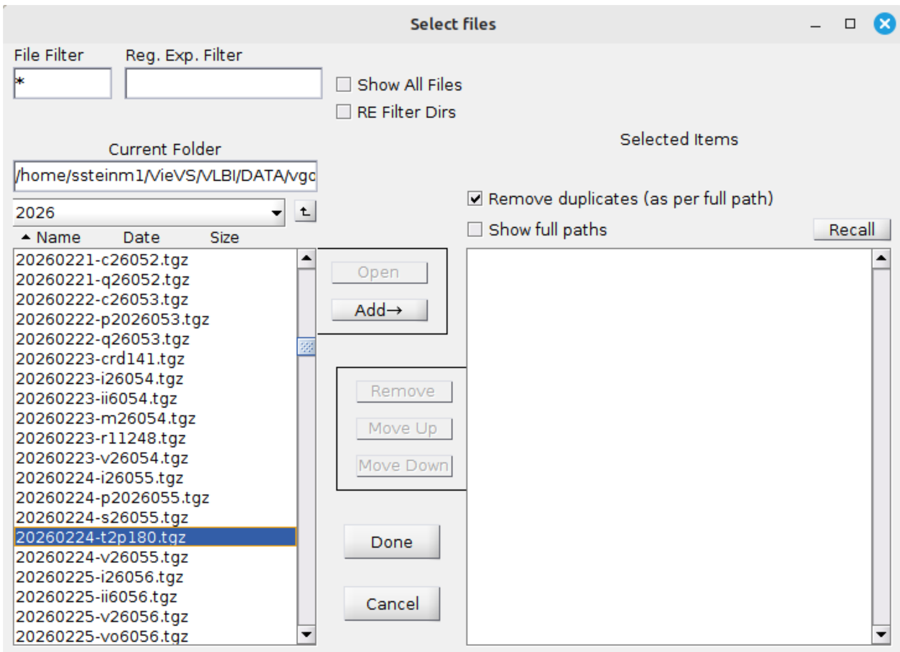
3 Starting VieVS

- start MATLAB
- browse to your VieVS working directory *"VieVS/VLBI/WORK/"*
- type *"vievs"* in the MATLAB command window

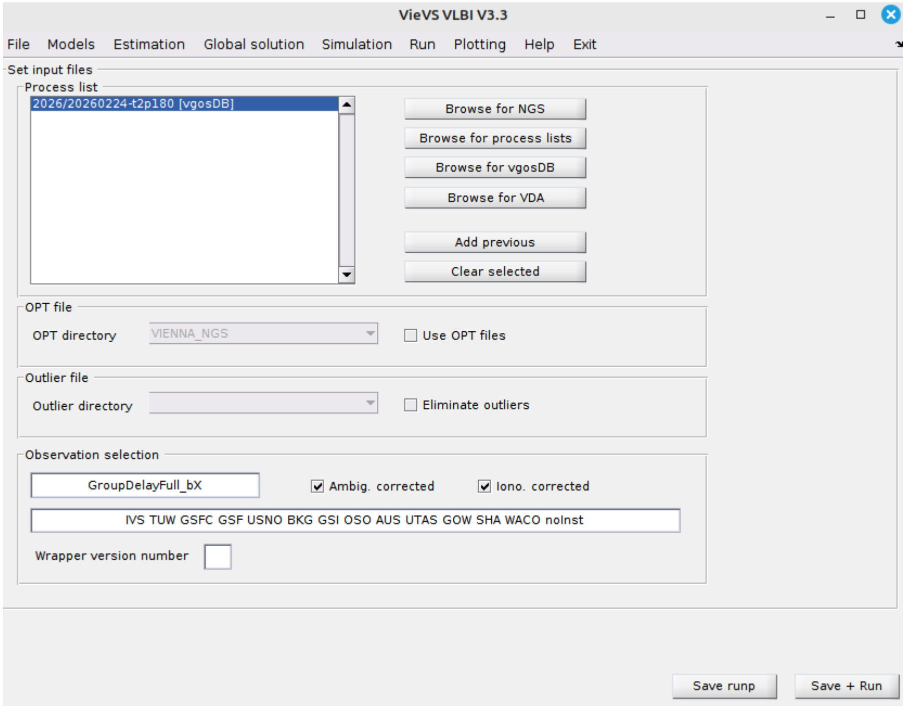
now VieVS should open

4 Select input files

Select the input vgosDB file in *"File/Set input files/Browse for vgosDB"*. Add the **20260224-t2p180** vgosDB file from the **2026** folder. If it is listed under *"Selected Items"*, click *"Done"*.



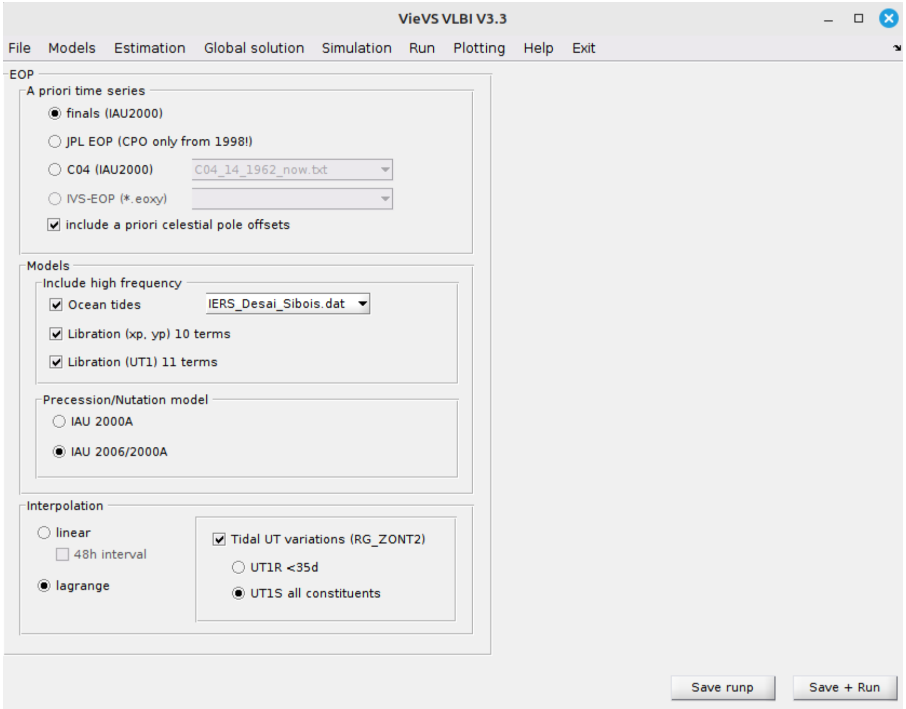
Now the file should be listed in the *“Process list”*.



Check the *“Use OPT files”* checkbox and select the *“VIENNA_VGOSDB”* folder in the dropdown menu. Right-click the session name in the process list and select *“Open/Create OPT file”*. An OPT file is a text file that lists some additional information about the analysis of the session, like clock breaks or stations, sources, and baselines that should be excluded. Those specifications are applied to the session analysis and therefore influence the results. It is saved to the folder *“VieVS/VLBI_OPT/VIENNA_VGOSDB/<year of session>”*.

5 Look at model settings

Select the menu *“Models/*”* to specify which models should be used for the session analysis. At *“Models/EOP”* select *“finals”* at the top. For the other model settings, we can choose the default options.



6 Look at estimation settings

Select the menu *"Estimation/Least squares/*"* and look at the parameters that should be estimated.

- What do we estimate?
- How often do we estimate parameters?
- How are they constrained?

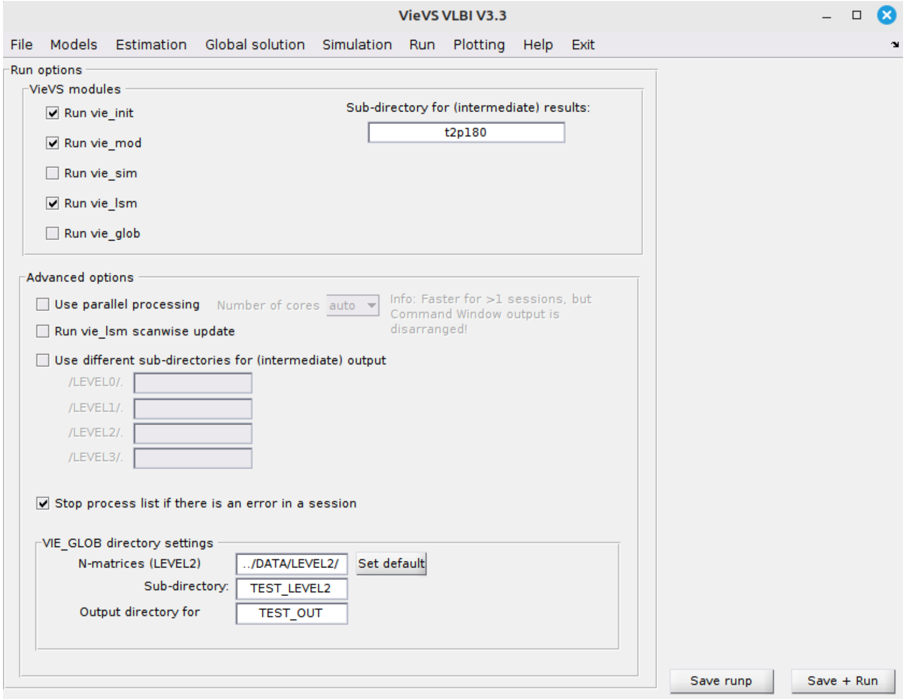
At *"Estimation/Least squares/Clock"*, check *"Estimate baseline-dependent clock offset"* in order to be able to add the relevant baselines to the OPT file in a later step.

7 Compute theoretical delay and estimate parameters

Click on the menu *"Run/Run options"* and select the following VieVS modules:

- VIE_INIT
- VIE_MOD
- VIE_LMS

Choose a new **sub-directory name** for (intermediate) results like *t2p180* and press *"Save + Run"*.



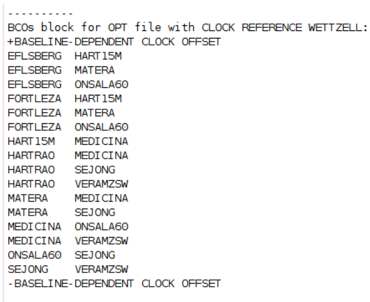
In the command window output, you will find information about the processing steps of the session analysis. At the end, indicators of the session quality are printed. The chi^2 value indicates how well the model fits the observations. In a perfect scenario, it equals 1. To get a feeling for the analysis performance, you can compare the WRMS of your post-fit residuals to the one in the analysis report on the IVS homepage. In our case, it is relatively high, which indicates problems with the session that need to be solved.

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
chi-squared of main solution vTPv/degOfFreedom: 4.830
WRMS of post-fit residuals sqrt(v_realTPv_real/sumOfWeights): 1.406 cm (46.911 ps)
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

The theoretical delay is saved during VIE_MOD, and you can **deselect vie_init and vie_mod** for improved performance during the upcoming runs.

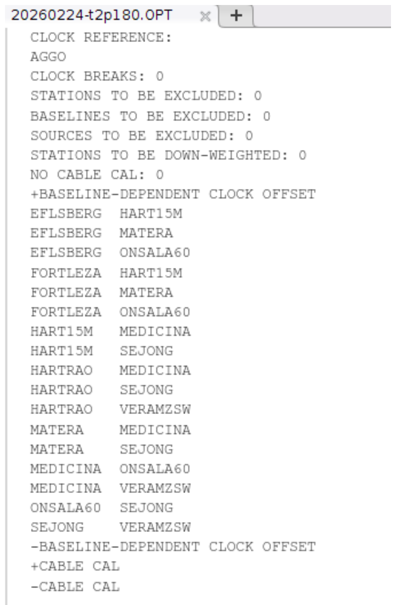
8 Baseline dependent clock offsets

From the output in the command window, copy the baselines in the block *“Baseline dependent clock offsets”*, paste them in the corresponding block in the OPT file, and save the OPT file.



```
----------
BCOs block for OPT file with CLOCK REFERENCE WETTZELL:
+BASELINE-DEPENDENT CLOCK OFFSET
EFLSBERG  HART15M
EFLSBERG  MATERA
EFLSBERG  ONSALA60
FORTLEZA  HART15M
FORTLEZA  MATERA
FORTLEZA  ONSALA60
HART15M   MEDICINA
HARTRAO   MEDICINA
HARTRAO   SEJONG
HARTRAO   VERAMZSW
MATERA    MEDICINA
MATERA    SEJONG
MEDICINA  ONSALA60
MEDICINA  VERAMZSW
ONSALA60  SEJONG
SEJONG    VERAMZSW
-BASELINE-DEPENDENT CLOCK OFFSET
```

Figure 1: VieVS output



```
20260224-t2p180.OPT
CLOCK REFERENCE:
AGGO
CLOCK BREAKS: 0
STATIONS TO BE EXCLUDED: 0
BASELINES TO BE EXCLUDED: 0
SOURCES TO BE EXCLUDED: 0
STATIONS TO BE DOWN-WEIGHTED: 0
NO CABLE CAL: 0
+BASELINE-DEPENDENT CLOCK OFFSET
EFLSBERG  HART15M
EFLSBERG  MATERA
EFLSBERG  ONSALA60
FORTLEZA  HART15M
FORTLEZA  MATERA
FORTLEZA  ONSALA60
HART15M   MEDICINA
HART15M   SEJONG
HARTRAO   MEDICINA
HARTRAO   SEJONG
HARTRAO   VERAMZSW
MATERA    MEDICINA
MATERA    SEJONG
MEDICINA  ONSALA60
MEDICINA  VERAMZSW
ONSALA60  SEJONG
SEJONG    VERAMZSW
-BASELINE-DEPENDENT CLOCK OFFSET
+CABLE CAL
-CABLE CAL
```

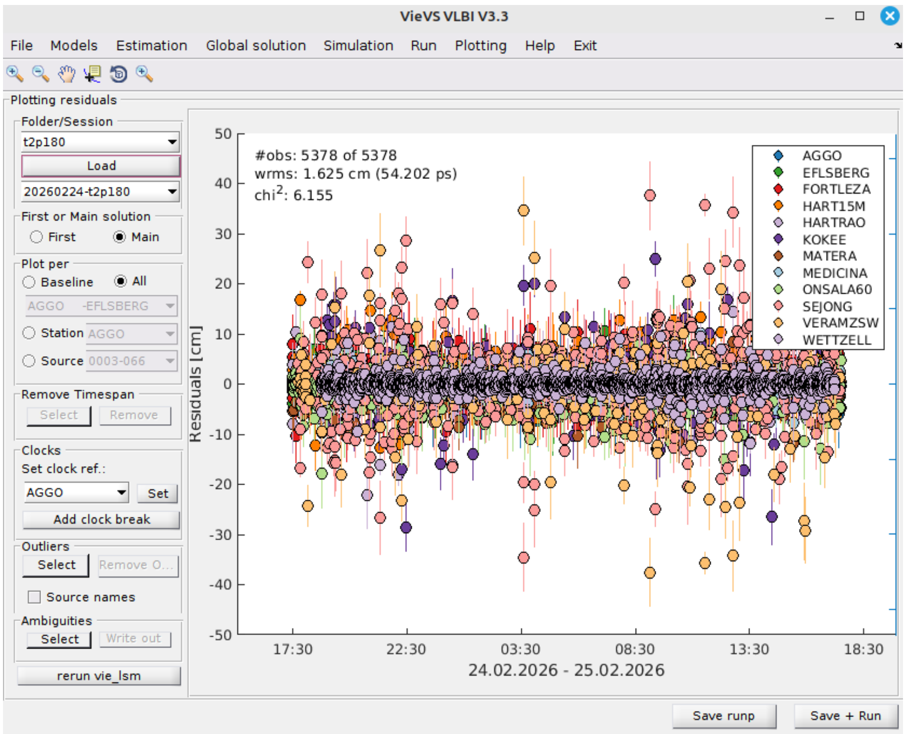
Figure 2: OPT file

In the VieVS GUI, go to *"Estimation/Least squares/Clock"* and select *"according to OPT-file"* at the bottom to specify how the baseline-dependent clock offsets should be estimated.

9 Plot the residuals

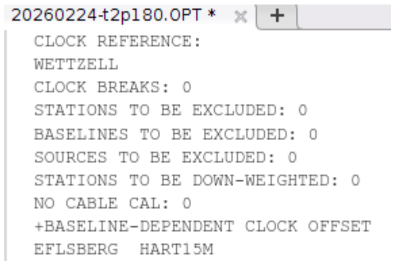
Browse to *"Plotting/Residuals"* and select your previously defined directory name from the box at the top left and load your session.

Have a look at the residuals of your observations. You can switch between the first and the main solution and filter for stations, sources, and baselines. Ideally, the residuals should look normally distributed around 0. The final chi^2 and WRMS values can be seen if the main solution is selected.



10 Clock reference

In VieVS, the clock from the first station in the list is set as the reference clock. In this case, it is the station AGGO. By looking at the residuals of the first solution station-wise, you can see that the residuals of AGGO are not distributed normally around 0. It would be good to set the reference clock to a clock of a station that has a stable clock and a relatively high number of observations, like WETTZELL. This can be done in the *"Clocks"* section on the left. Select the station whose clock should be the reference clock in the drop-down menu and click the *"Set"* button. Confirm your choice by clicking *"Yes"*. Now the OPT file should contain the content as shown in the following image.

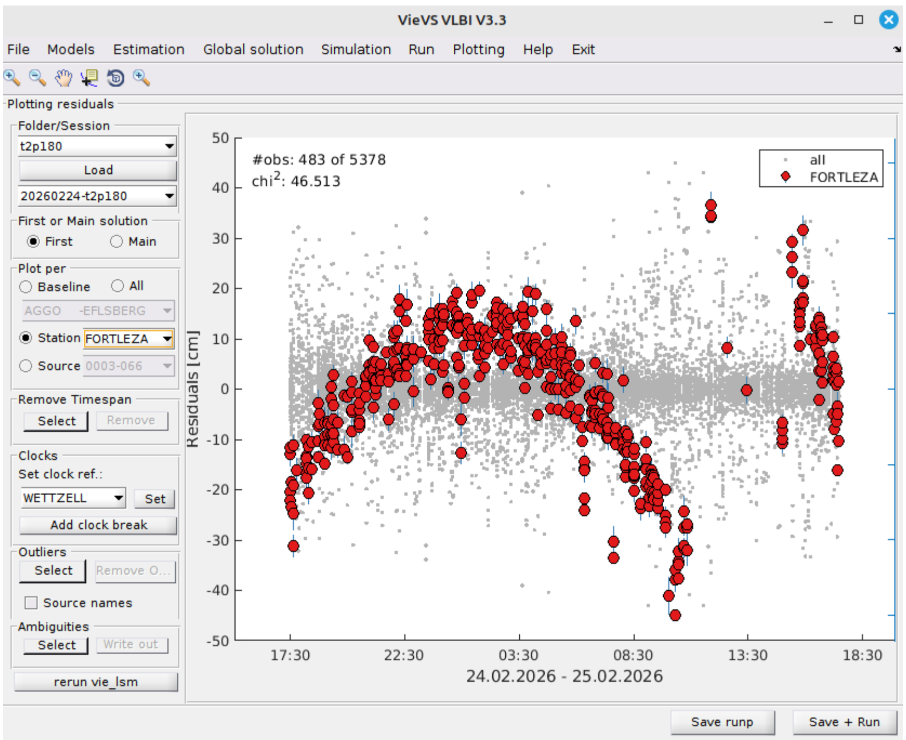

20260224-t2p180.OPT *

```
CLOCK REFERENCE:
WETTZELL
CLOCK BREAKS: 0
STATIONS TO BE EXCLUDED: 0
BASELINES TO BE EXCLUDED: 0
SOURCES TO BE EXCLUDED: 0
STATIONS TO BE DOWN-WEIGHTED: 0
NO CABLE CAL: 0
+BASELINE-DEPENDENT CLOCK OFFSET
EFLSBERG  HART15M
```

The previous steps were part of a basic single session analysis. However, for some sessions, additional adjustments are necessary, which are shown in the following.

11 Clock breaks

It is necessary to look for **clock breaks** in the *"Plotting/Residuals"* window. Clock breaks can be found most easily by filtering for station-wise residuals and looking at the first solution. The first solution approximates the clock only as one offset, one rate, and one quadratic term (no piecewise linear offsets are calculated, which would follow the clock break behavior and would therefore mask it in the residuals). If there are **jumps in the residuals** like in the following image for the station FORTLEZA, it is most likely due to clock breaks at that epochs.



To remove a clock break, you can zoom in with the magnifying glass button at the top left in order to see the jump nicely. Click the *"Add clock break"* button. Your mouse pointer should now change to a crosshair. **Click between the residual jump** and confirm that you want to add a clock break there. It doesn't matter where exactly you click as long as it is in between the residual jump.

The clock break should now be listed in your OPT file. Make sure you selected *"use OPT files"* at *"File/Set input files"* and click *"Save + Run"* again to run another least squares adjustment with the additional clock break information. After the process is finished, you have to load the result in the *"Plotting/Residuals"* window again. Check if the clock break is gone.

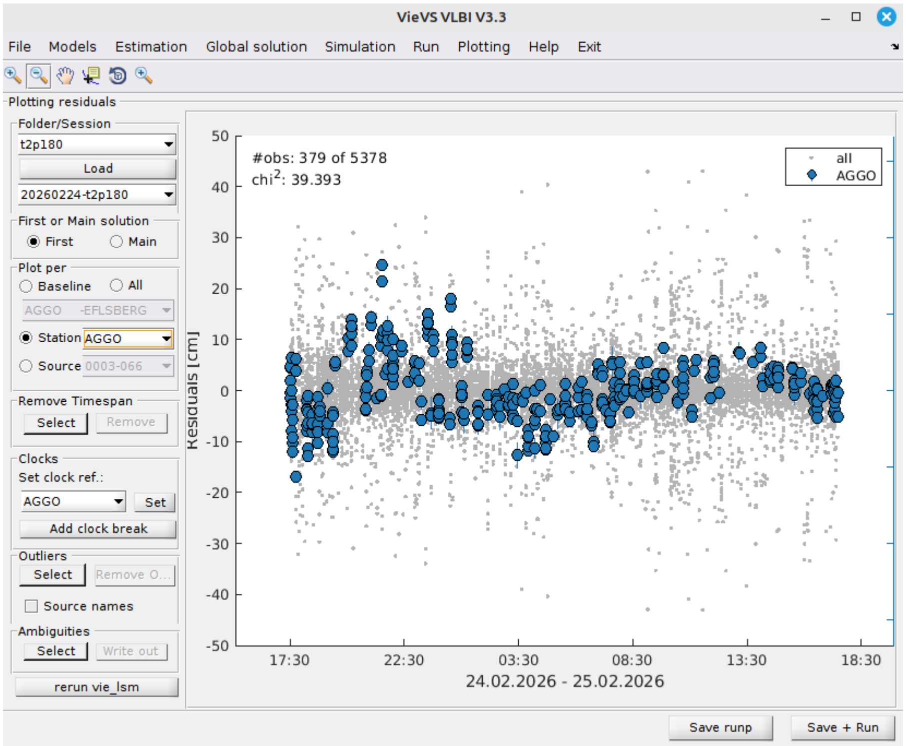
Repeat these steps until you do not see any clock breaks in your session. In this case, there are two clock breaks at the station FORTLEZA.

Hint:
If you messed up your session somehow, you can always manually remove clock breaks again by looking at the OPT file and deleting the corresponding line. Do not forget to change the clock break counter in the header. If you messed up completely, delete the whole OPT file. You can find the OPT file in the directory *"VieVS/VLBI_OPT/VIENNA_VGOSDB/<year of session>"*.

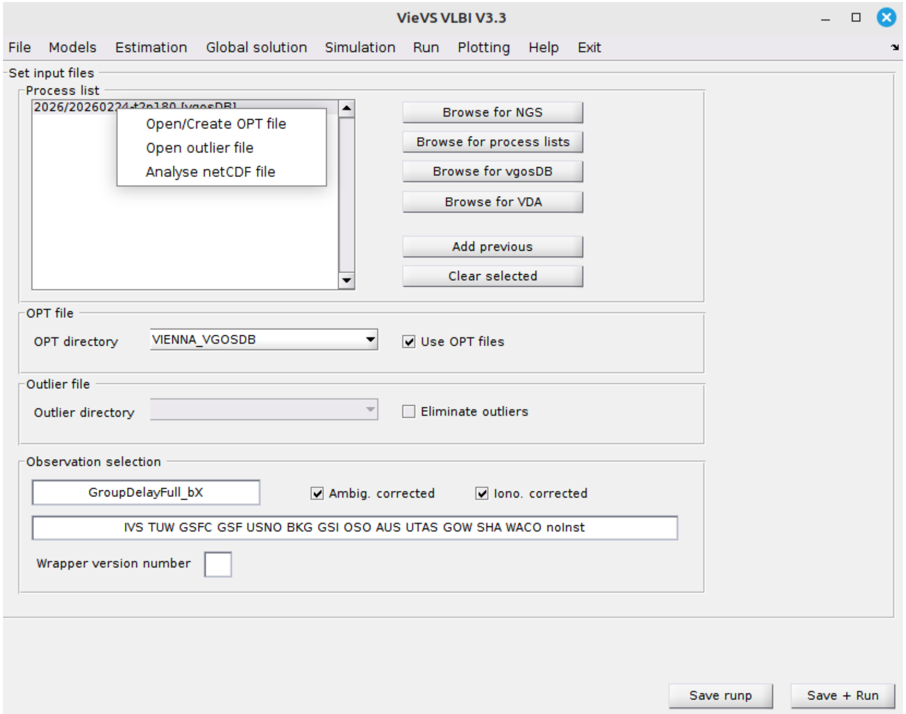
After removing the clock breaks and running the session again, the *chi*^{2} still has a rather high value. This indicates that there are still some issues that need to be fixed. A good way to find them is to look at the residuals station-wise (first and main solution). If doing so, pay attention to the scale of the y-axis.

12 Cable calibration

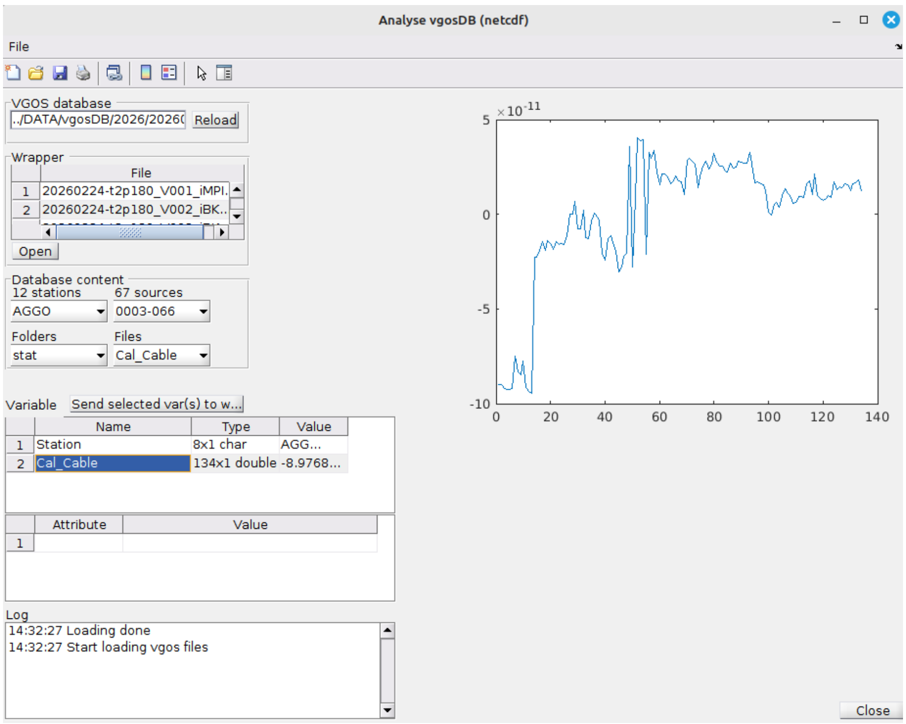
By looking through the residuals station-wise, you can see that the residuals for AGGO don't really follow a normal distribution around 0.



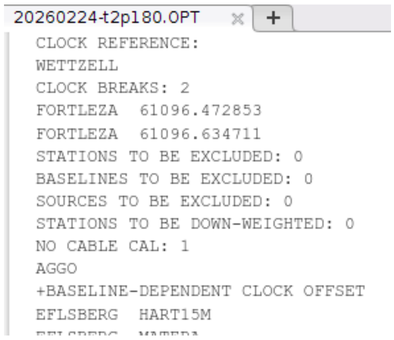
This can indicate a problem with the cable cal delay measurements, and applying them degrades the solution. For more information about the cable cal measurements, use the VieVS vgosDB Analyzer. This analyzer allows you to view the contents of vgosDB NetCDF files. Start the analyzer by right-clicking on the session in the list of loaded sessions and selecting *"Analyze netCDF file"*.



The database content is structured in folders. First, select the station AGGO in the station folder and then the *"stat"* folder in the box below. Once you have selected a folder, you can select a file in the *"Files"* dropdown menu. Select the *"Cal_Cable"* file. After selecting the file, the list of variables (parameters) stored in that file is displayed in the variables table. The table shows information about the name, type, and value of each parameter. To plot the data of a parameter, simply click on the desired parameter. In the plot, you can see that the cable cal data has a jump at the beginning, which is not usual.

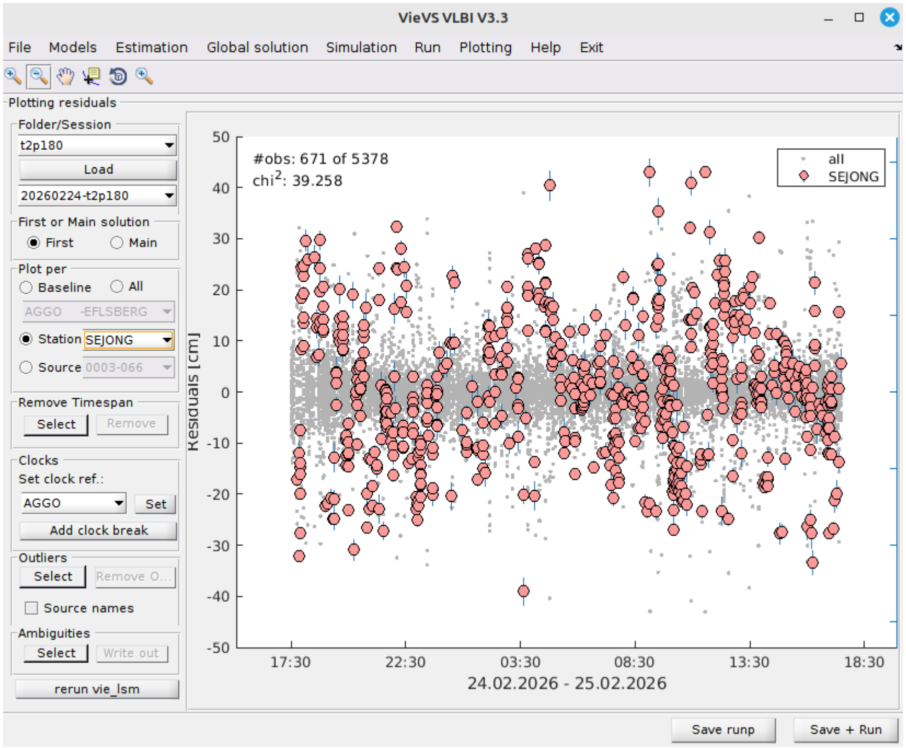


It is possible not to apply the cable cal information by stating this in the OPT file. You have to enter the number of stations and the station names for which you don't want to use the cable cal information. The OPT file, including the added clock breaks and the cable cal exclusion for AGGO, is depicted below.

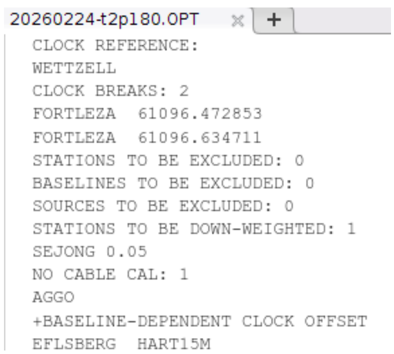


13 Down-weight station

Sometimes the observations of a station should be down-weighted in order to reduce their influence. In this case, the residuals of the station SEJONG are rather large.

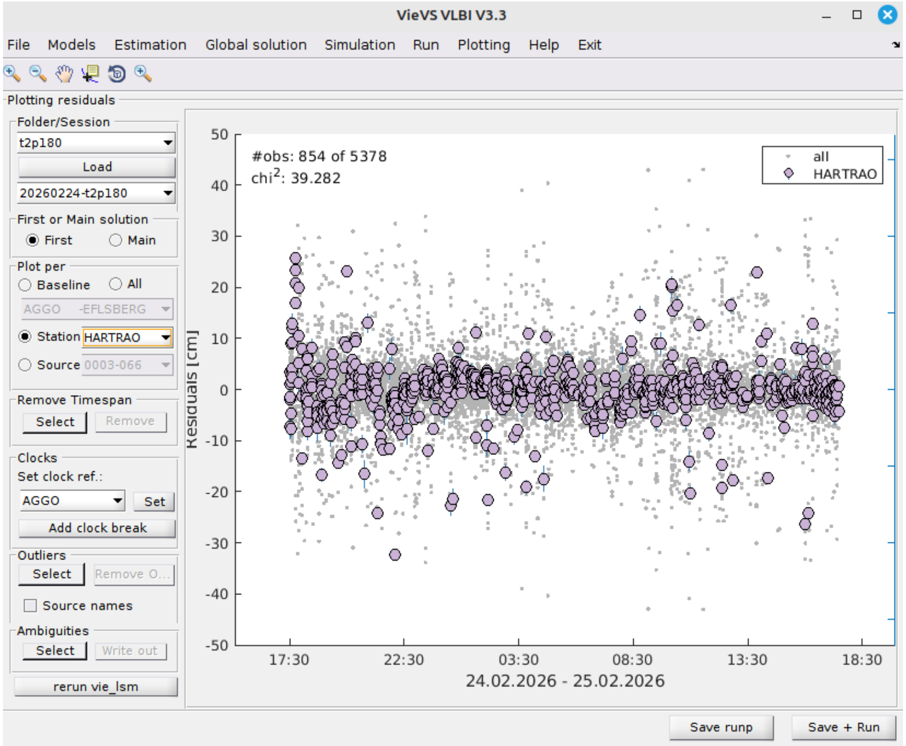


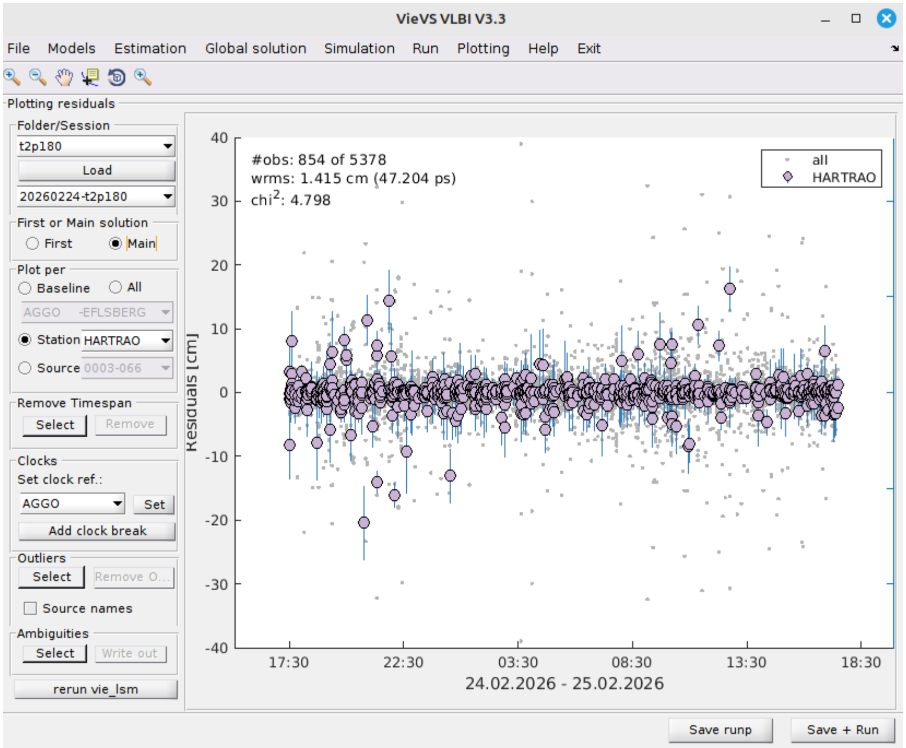
In order to down-weight the observations of a station, a weight can be specified in the OPT file. Increase the number of stations that should be down-weighted to 1 and write the name of the station on the next line. Set the weight to 0.05 (corresponding to 5 cm) as done in the image below and save the OPT file.



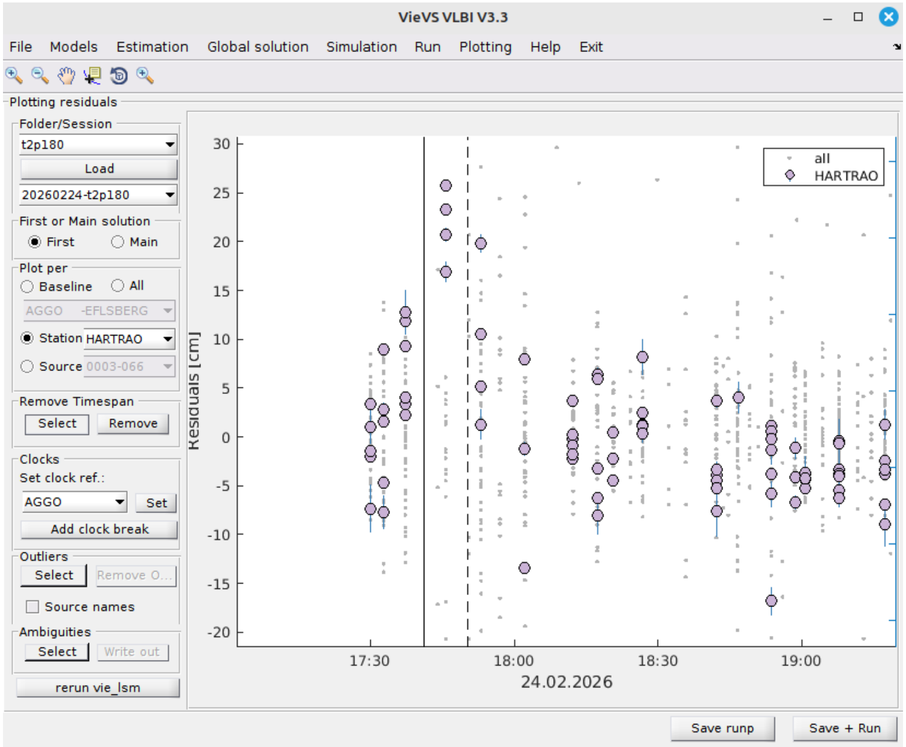
14 Exclude observations

Check the residuals again at *"Plotting/Residuals"*. By looking through the residuals station-wise, you can see that there are some outliers at the station HARTRAO around 6 pm (18:00) in the first and in the main solution. Those are not crucial but in order to get familiar with another useful tool, we will remove them.





It is possible to exclude observations from a station for a specific time span. To exclude these observations, you should change the zoom to see the outliers clearly. Make sure to unclick the zoom button again. Now click the *"Select"* button in the *"Remove Timespan"* section on the left. You can select the outliers by pressing and holding the mouse button at the start of the time span you want to remove. When you move your mouse, two lines will appear. These lines mark the start and end of the selected time span. In this way, you can select the observations to be removed. The image below shows the lines marking the specific time span for removing the outliers. The observations within these two lines will be removed. If you are satisfied, you can now remove the outliers by clicking the *"Remove"* button next to the *"Select"* button in the *"Remove Timespan"* section and confirming that you want to remove these observations.



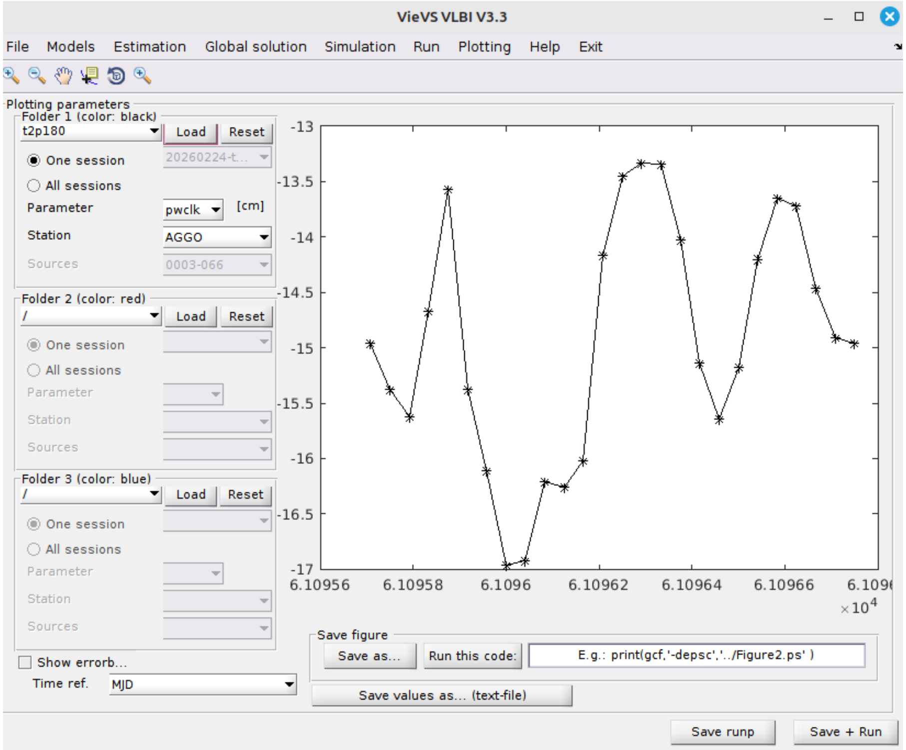
The timespan that will be excluded for the station HARTRAO is now listed in the OPT file. Click *"Save + Run"* again to run another least squares adjustment excluding these observations.

After removing the clock breaks, not applying the cable cal information for AGGO, reducing the weight for SEJONG, and removing the outliers of HARTRAO, the chi^2 is 1.628 and the residuals follow a normal distribution. The WRMS of the post fit residuals has a value of 0.840 cm or 28.021 ps, which is close to the value in the analysis report of 27.390 ps. If the values are not exactly the same for you, you might have placed the clock break at a slightly wrong position or excluded more or less observations for HARTRAO.

15 Output

15.1 Estimated parameters

The estimated parameters can be viewed at *"Plotting/Parameters"*. Select your previously defined directory name from the box at the top left and load your session.



For some parameters, we are also interested in the **accuracy** of the parameter instead of the **estimate**. You can add the error bars by checking the *"Show errorbar"* checkbox at the bottom left. You can switch between different parameters. The values per parameter can be **saved in a text file** using the *"Save values as... (text file)"* button and specifying a name. Do not forget that these are just additions to a priori values! The text file is saved in *"VieVS/VLBI/OUT/"*.

15.2 Data stored in MATLAB structure

For easier access to the estimated values and accuracies, have a look at the *"VieVS/VLBI/DATA/LEVEL3/..."* directory. There you should find the *"x_*"* MATLAB structure, which contains all estimates. You can simply load it with MATLAB and do some further analysis.

15.3 SINEX file

SINEX is a standard output format for geodetic parameters. If you want to create these text files, go to *"Run/Sinex output"* and tick the checkbox *"write SINEX file"*. Here you can select the parameters to be included in the SINEX file by switching the radio buttons. Note that the SINEX file could become very large if all parameters are written to it. Now, you need to rerun the session to create the SINEX file. The file can be found in the directory *"VieVS/VLBI/DATA/SNX"*.