

Single Session Analysis using VieVS

1 Exercise 1

1.1 Description

This exercise will give a short introduction to the possibilities to analyze VLBI observations using the Vienna VLBI and Satellite Software (VieVS). In the following the IVS session RD1904 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 all the information about sessions run by the IVS is stored.

1.2 Before you start

- download VieVS from <https://github.com/TUW-VieVS/VLBI>

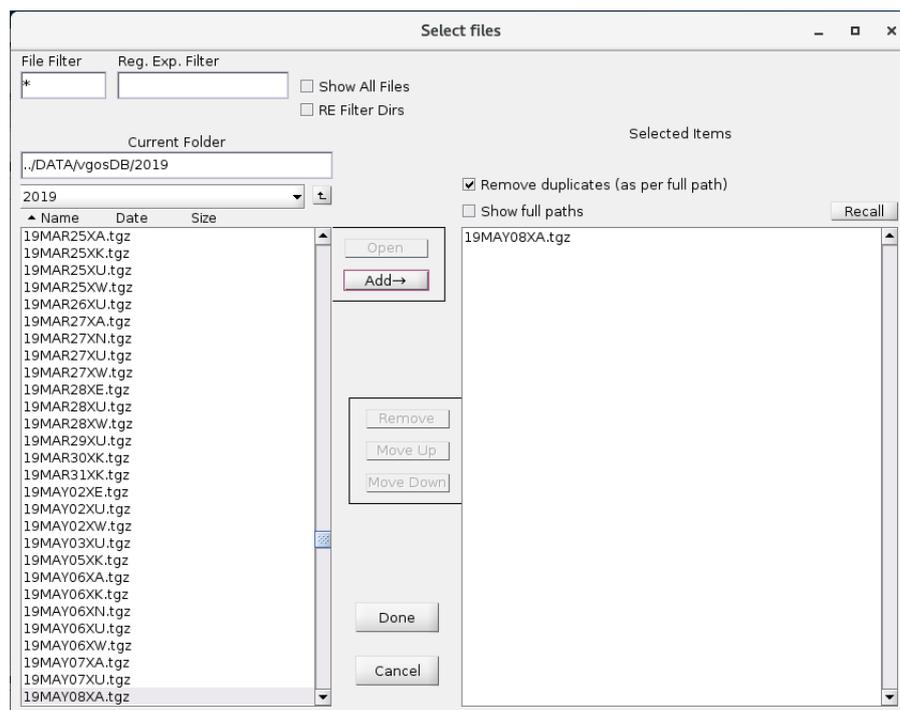
1.3 Starting VieVS

- start MATLAB
- browse to your VieVS working directory *VieVS/VLBI/WORK/*
- type “*views*” in the MATLAB command window

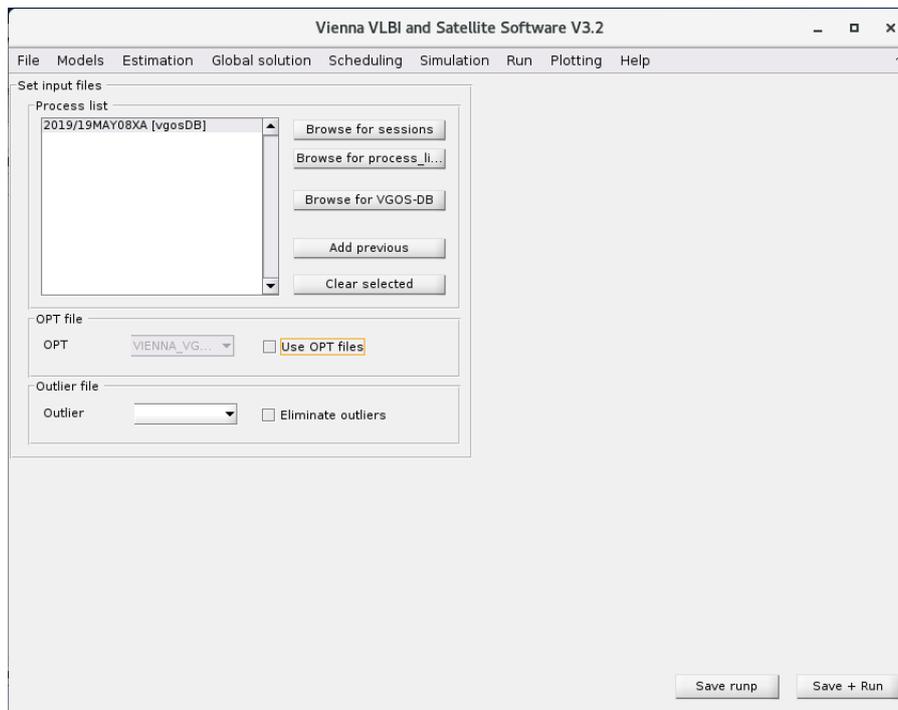
now VieVS should open

1.4 Select input files

Select the input vgosDB file in “*File/Browse for VGOS-DB*”. Add the **19MAY08XA** (IVS-RD1904) vgosDB file from the **2019** 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 from the process list and select “*Open/Create OPT file*”. A OPT file is a text file which lists some additional information about the analysis of the session like clock breaks or stations, sources, and baselines which should be excluded.

It is likely that you need the OPT file later. You can close it for now.

1.5 Look at Estimation settings

Select the menu “*Estimation/Least squares/**” and look at the parameters which should be estimated.

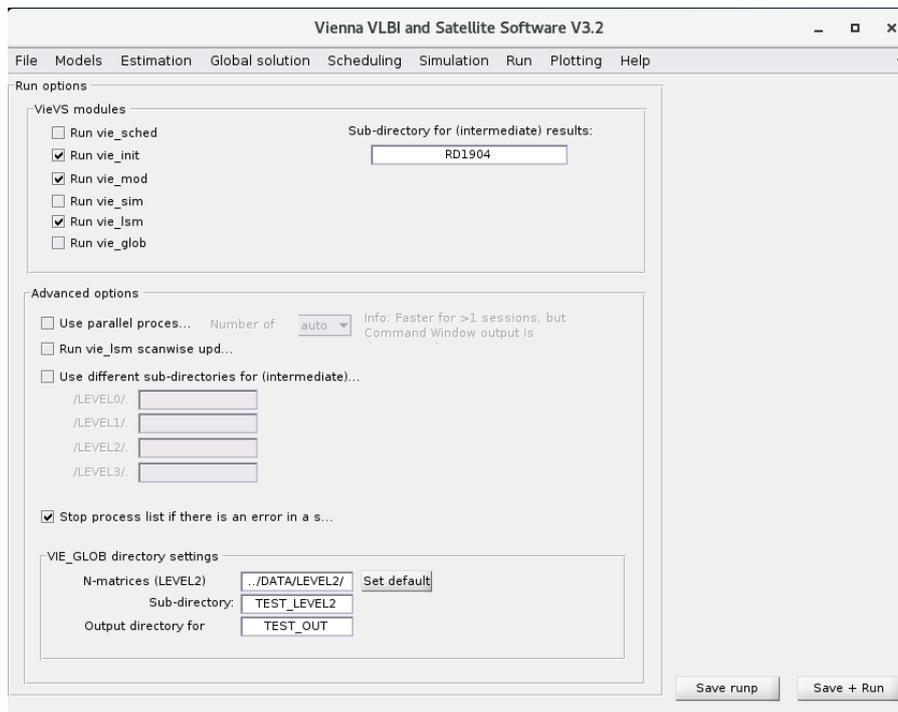
- What do we estimate?
- How often do we estimate parameters?
- How are they constraint?

1.6 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 *RD1904* and press “*Save + Run*”.

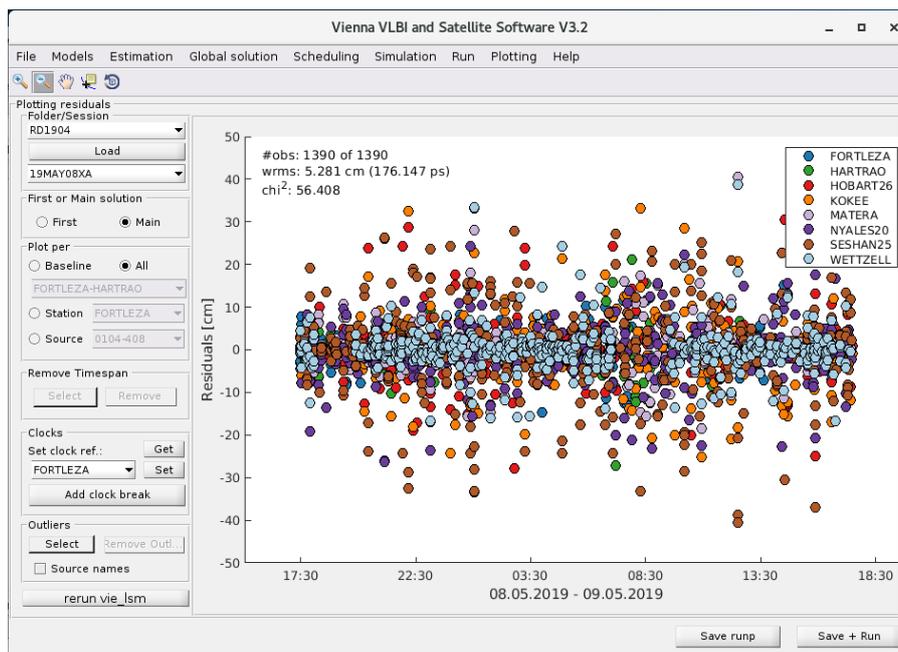


The theoretical delay is saved during VIE_MOD and you can **deselect** `vie_init` and `vie_mod` for improved performance during the upcoming runs.

1.7 Look for clock breaks and other issues

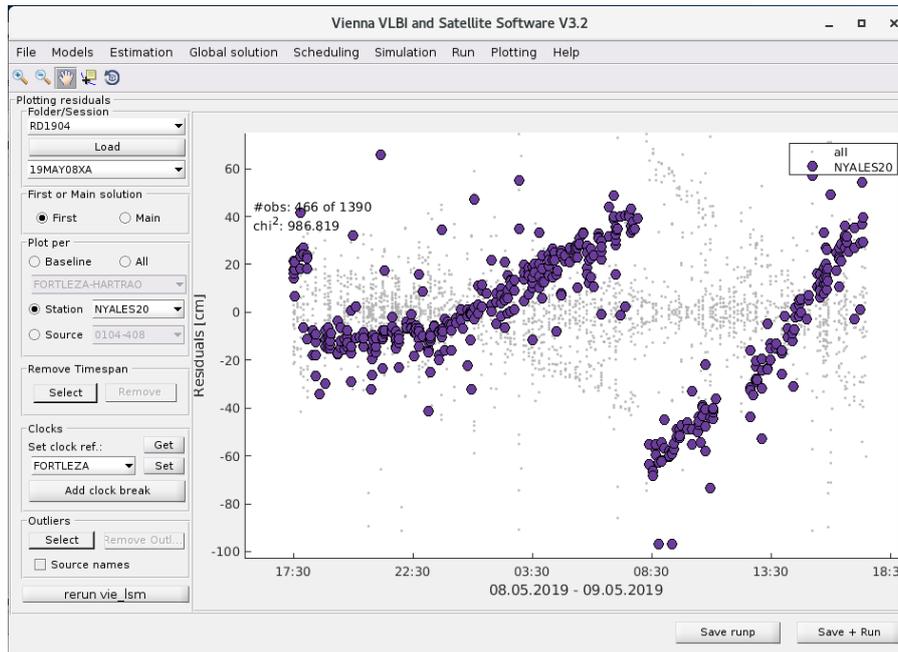
Browse to “*Plotting/Residuals*” and select your previously defined directory name from the combo box at the top left and load your session.

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 and the χ^2 should be close to 1. χ^2 indicates how well your model fits your observations. The WRMS of your post-fit residuals should be around 30 ps for a typical R1 or R4 session.



It is necessary to look for **clock breaks**. Clock breaks can be found easiest while filtering for station wise residuals and looking at the first solution. The first solution approximates the clock only as one

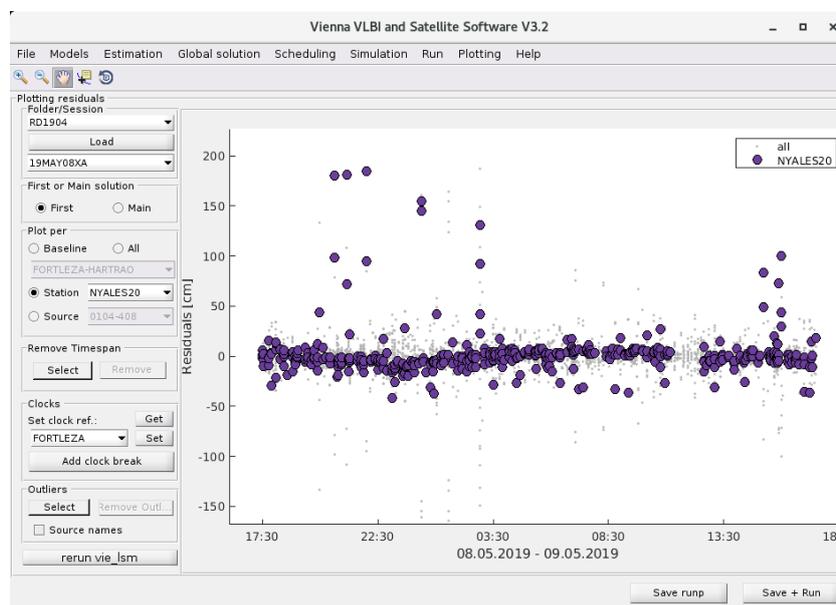
offset, one rate and one quadratic term (no piece wise linear offsets are calculated which would follow the clock break behaviour and would therefore mask it in the residuals). If you have a **jump in the residuals** like in the following image it is most likely due to a clock break.



To remove a clock break change the **zoom in** 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. After the process is finished you have to load the result in the *Plotting/Residuals* window again. Check if the clock break is now gone. (**Hint:** It might be wise to double check again)

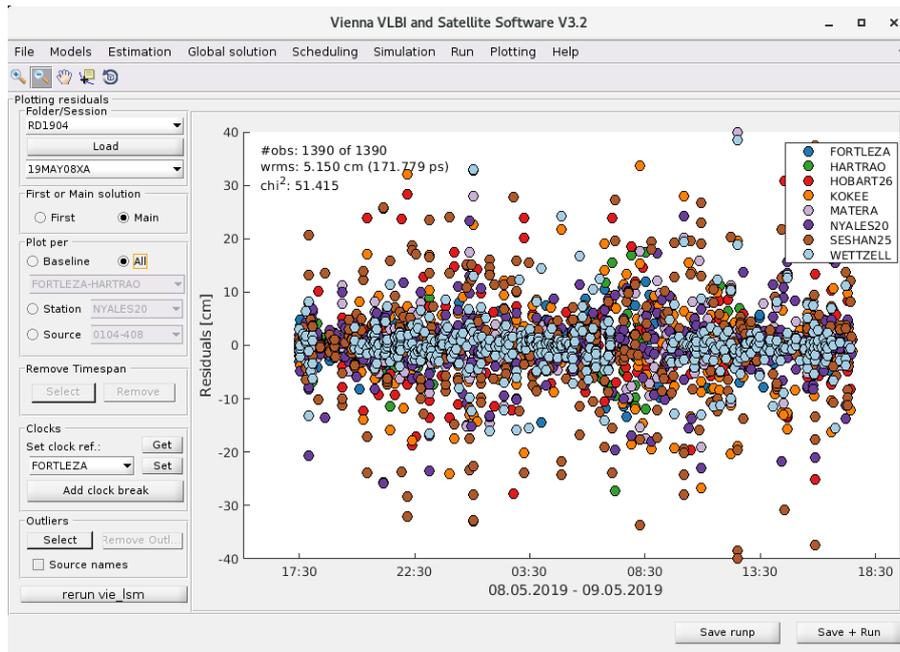
Repeat these steps as long as you do not see any clock breaks in your session. In this case, there are 2 clock breaks at the station NYALES20. In the following image you see the residuals after removing the clock breaks at NYALES20 - there are no jumps anymore.



Hint:

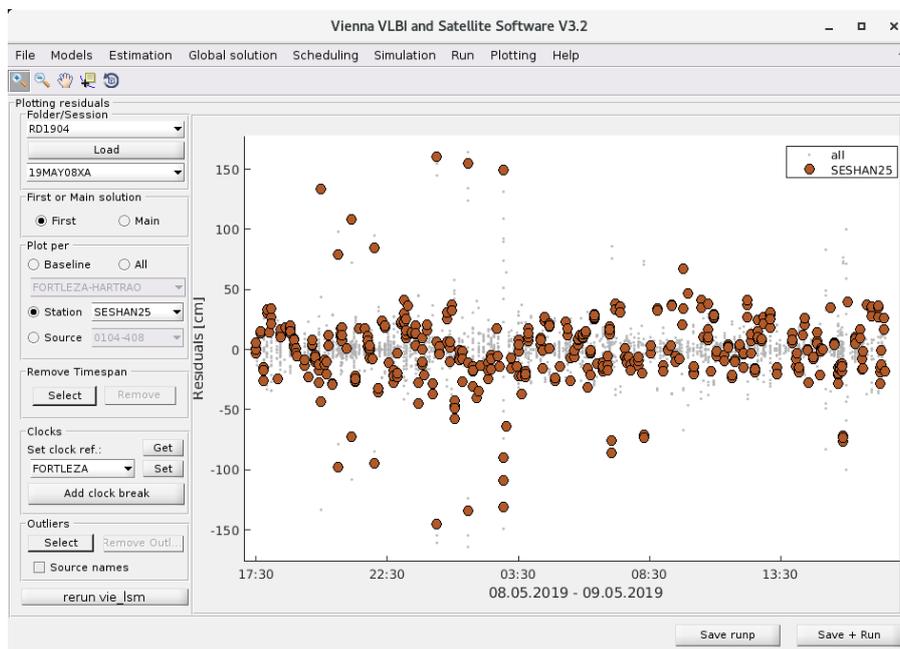
If you messed your session up somehow you can always manually remove clock breaks again by looking at the OPT file and deleting the corresponding line. Do not forget to change the clock break counter from the header. If you messed up completely delete the whole OPT file. You can find the OPT file in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

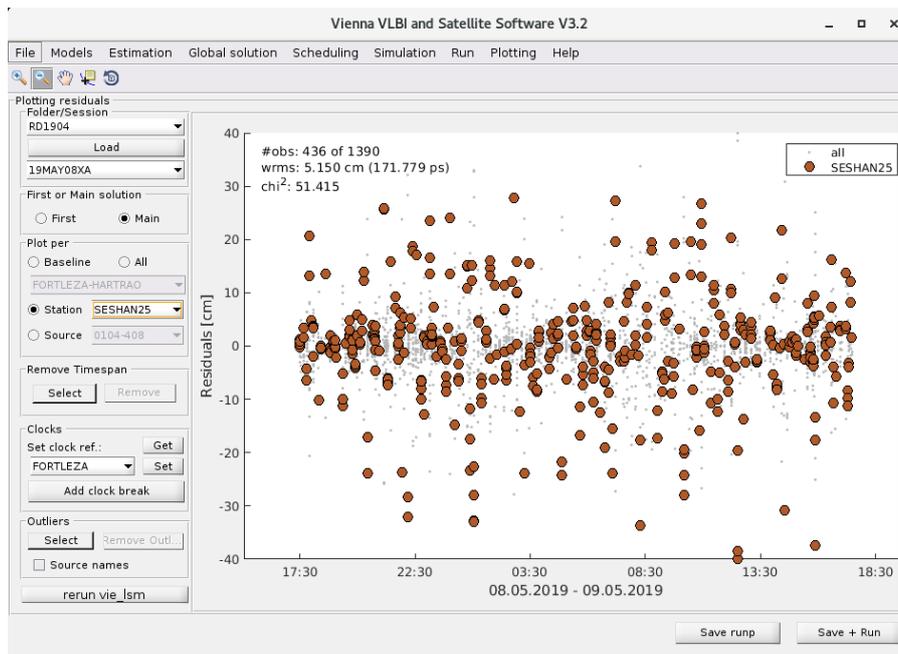
After removing the clock breaks the χ^2 has still a pretty high value of 51.415. In the image below you see the residuals after removing the clock breaks. The high value of χ^2 is a sign that there are still some issues which need to be fixed. A good way of finding them is to look at the residuals station wise (first and main solution).



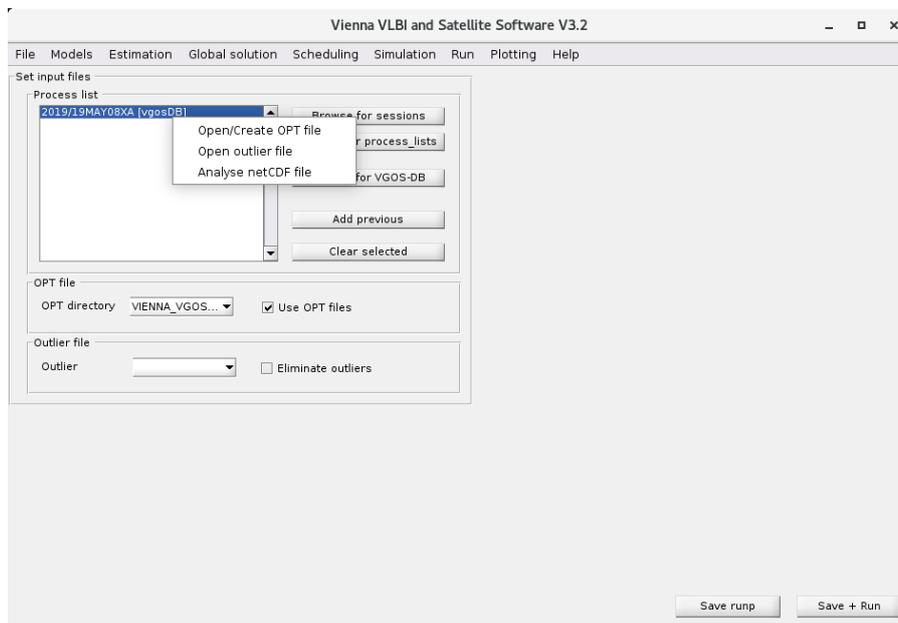
1.8 Cable Calibration

By looking through the residuals station wise you can see that the residuals for SESHAN25 don't really follow a normal distribution around 0. They are spreading a lot - in the first and in the main solution (see images below).

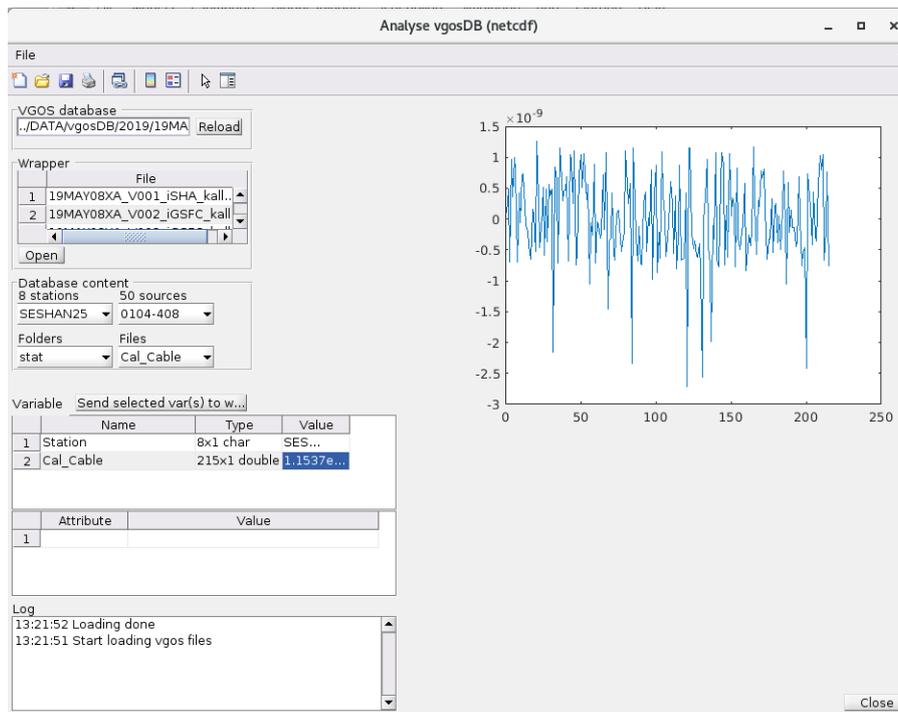




This can be a sign that there was a problem with the cable cal delay measurements and applying them degrades the solution. If you want to have more information about the cable cal measurements, you can use the VieVS vgosDB Analyzer. This analyzer offers the possibility to look at the content of the vgosDB NetCDF files. You can start the Analyzer with right click on the session in the list of loaded sessions and click an Analyze netCDF file. (see image below)



The Database content is structured in folders. First select the station SESHAN25 in the station folder and further the *stat* folder in the combo box below. Once you have selected a folder you can select a file in the Files dropdown menu. Select the *Cal_Cable* file. If you have selected the file the list of variables (parameters) stored in this file is displayed in the table of the variables. The table shows you information about the Name, Type and Value of the parameter. If you want to plot the data of a parameter, simply click on the desired parameter. In the plot you can see that the cable cal data is noisy and has a order of magnitude of 10^{-9} s which is larger than usual.



It is possible to not 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 SESHAN25 is depicted below.

```

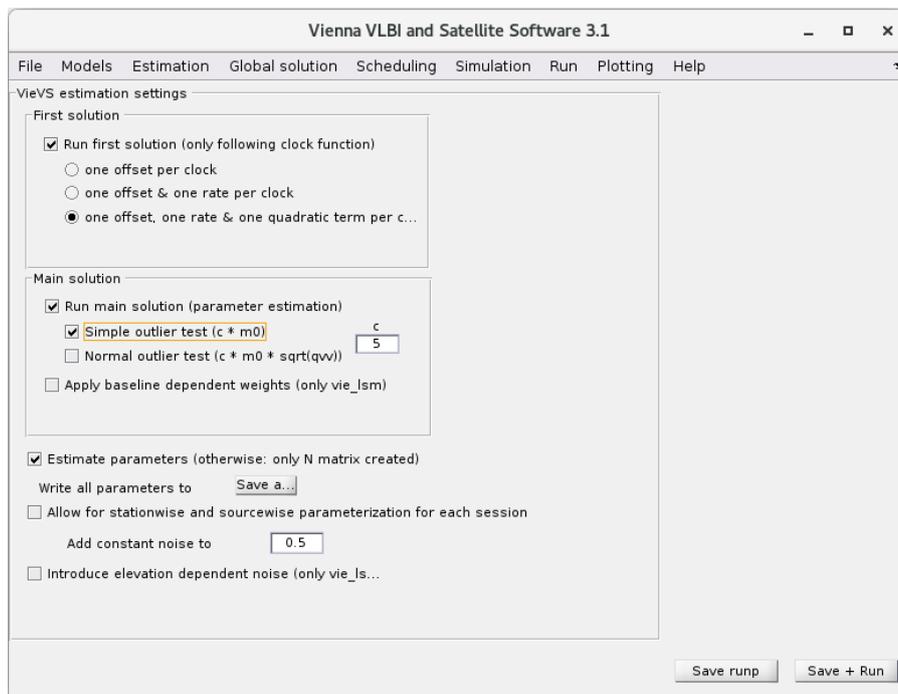
19MAY08XA.OPT
~/views/VieVS/VLBI_OPT/VIENNA_VGOSDB/2019

CLOCK BREAKS: 2
NYALES20 58611.758229
NYALES20 58612.340289
STATIONS TO BE EXCLUDED: 0
BASELINES TO BE EXCLUDED: 0
SOURCES TO BE EXCLUDED: 0
STATIONS TO BE DOWN-WEIGHTED: 0
NO CABLE CAL: 1
SESHAN25

```

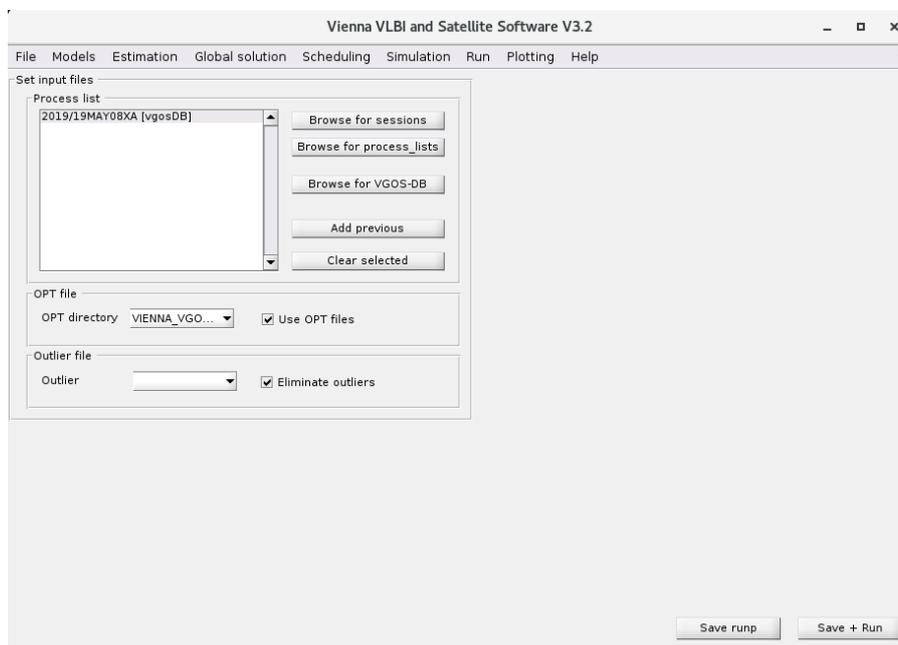
1.9 Remove outliers

Once other issues like clock breaks are resolved you can check the residuals again at *'Plotting/Residuals'* and check if there are any obvious outliers. If there are outliers it is necessary to remove them. Removing outliers is a two-step process. Click on the menu *"Run/VieVS estimation settings"* and check *"simple outlier test c*m0"*.

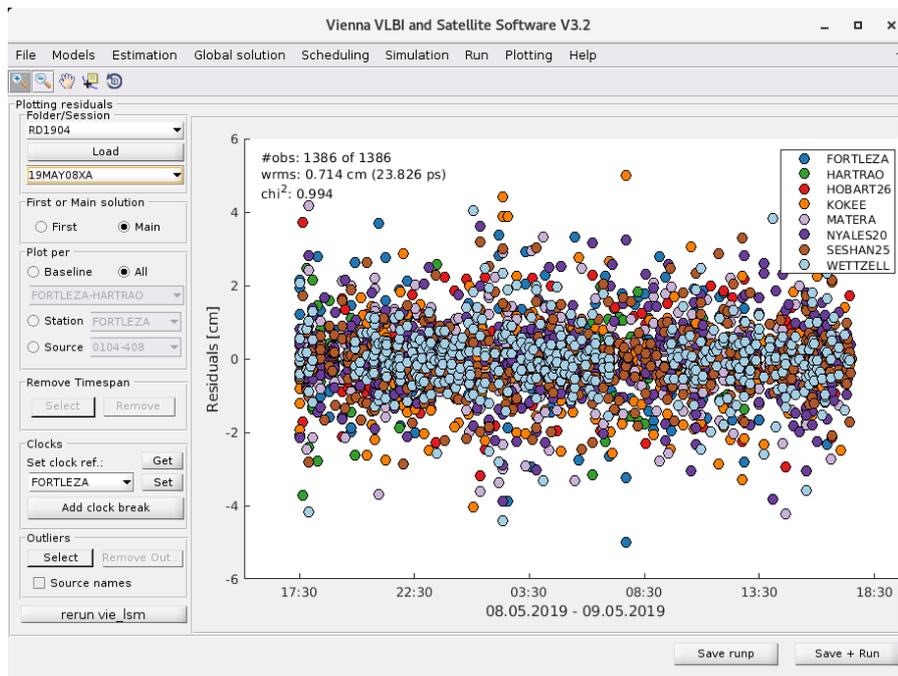


Press “*Save + Run*” to rerun the least squares adjustment. This time outliers are marked and an outlier list is saved. Have a look at the selected outliers through the “*Plotting/Residuals*” menu. You have to load the result again. Outliers are now marked with a black cross.

You need to rerun the least squares adjustment but this time eliminate the previously marked outliers. Therefore deselect the “*simple outlier test c*m0*” checkbox at “*Run/VieVS estimation settings*” again. At “*File/Set input files*” check the “*Eliminate outliers*” checkbox.



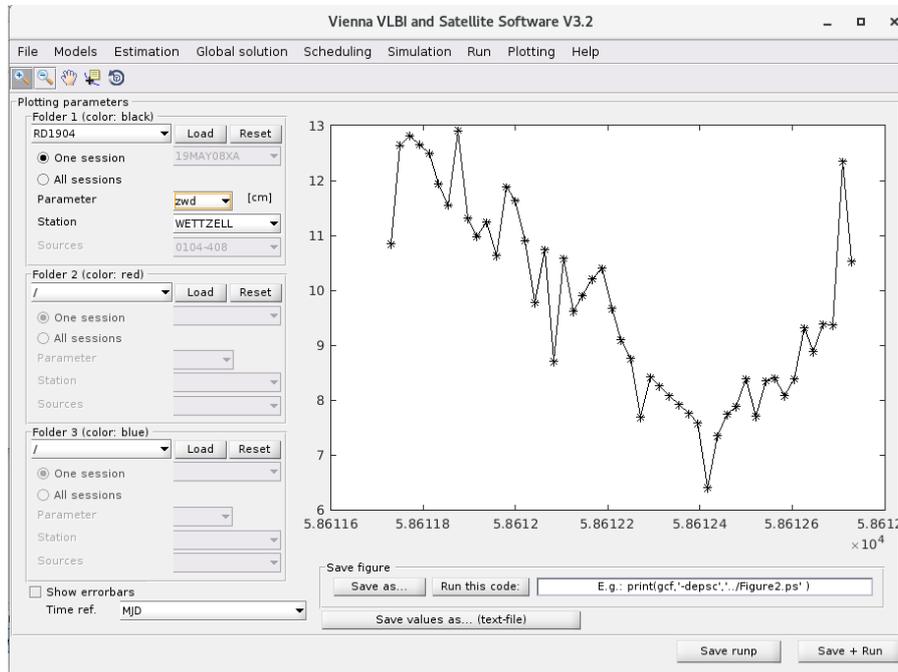
After removing the clock breaks, not applying the cable cal information for SESHAN25 and removing the outliers the χ^2 is 0.994 and the residuals follow a normal distribution.



1.10 Output

1.10.1 estimated parameters

The estimated parameters can be viewed at “*Plotting/Parameters*”. Select your previously defined directory name from the combo 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 errorbars by checking the “*Show errorbar*” checkbox at the bottom left. You can switch between different parameters. The values can be **saved in a text file** using the “*Save values as... (text file)*” button. Do not forget that this are just additions to a priori values! The text file is saved in “*VieVS/VLBI/OUT/*”.

1.10.2 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.

1.10.3 SINEX file

SINEX is a standard output format for geodetic parameters. If you want to create these textfiles, 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 when all parameters are written to the SINEX file. Now, you need to rerun the session to create the SINEX file. The file can be found in the directory *VieVS/VLBI/DATA/SNX*.

2 Exercise 2

2.1 Select input files

Load the VGOS-DB file for the session **19MAR11XA** (IVS-R1885) as it was described in the previous exercise.

Check the “*Use OPT files*” checkbox and select the “*VIENNA_VGOSDB*” folder. Right-click the session name from the process list and select “*Open/Create OPT file*”. It is likely that you need the OPT file later. You can close it for now.

2.2 Compute theoretical delay and estimate parameters

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

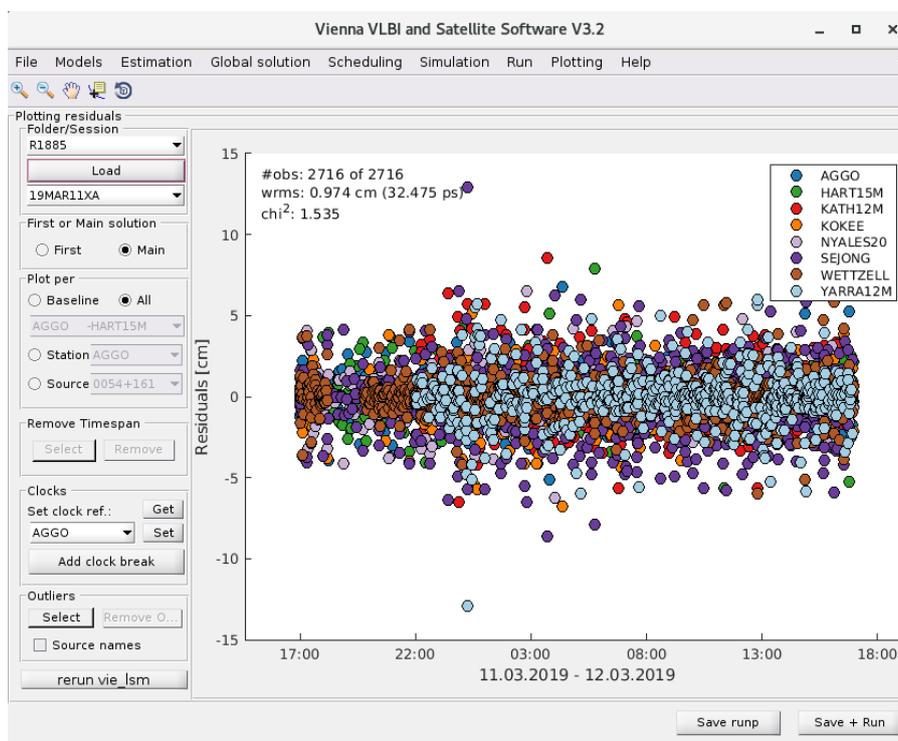
- VIE_INIT
- VIE_MOD
- VIE_LMS

Choose a new **sub-directory name** for (intermediate) results like *R1885* and press “*Save + Run*”. The theoretical delay is saved during VIE_MOD and you can **deselect `vie_init` and `vie_mod`** for improved performance during the upcoming runs.

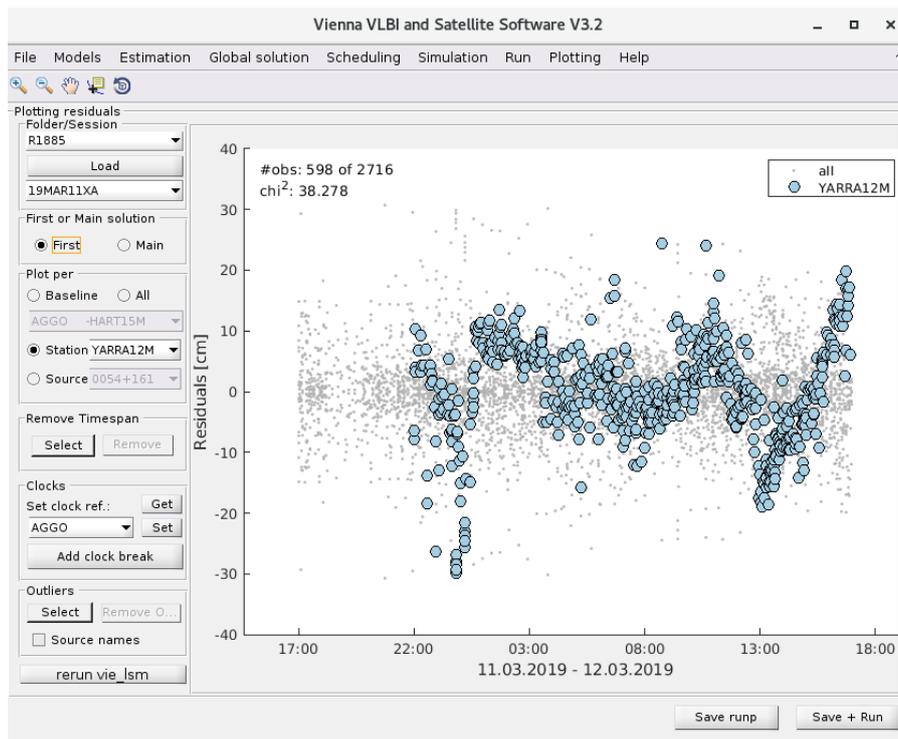
2.3 Look for clock breaks and other issues

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

Have a look at the residuals of your observations.

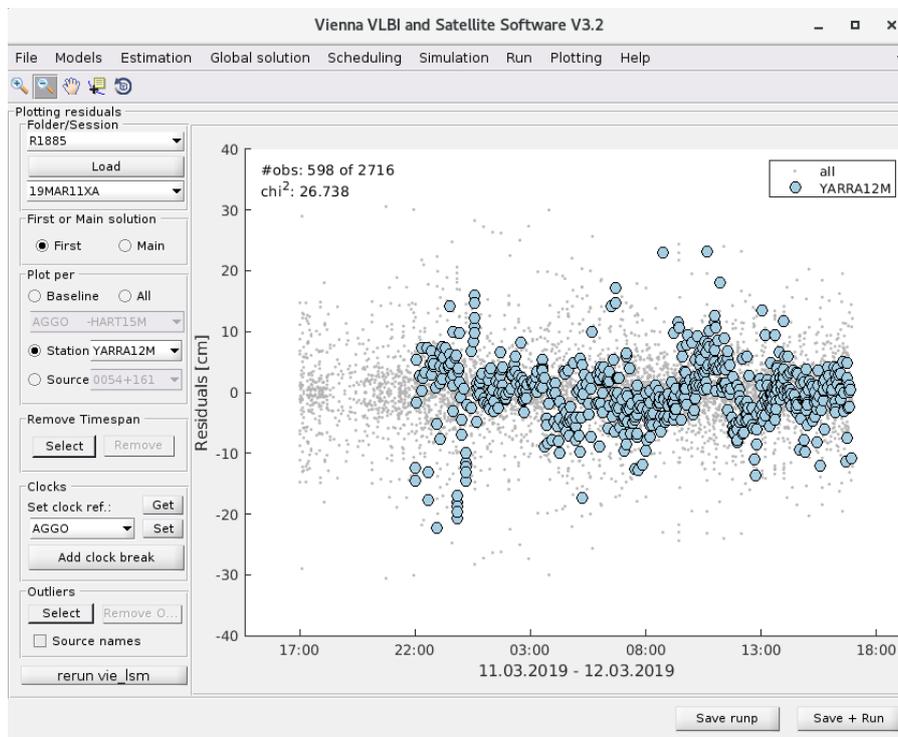


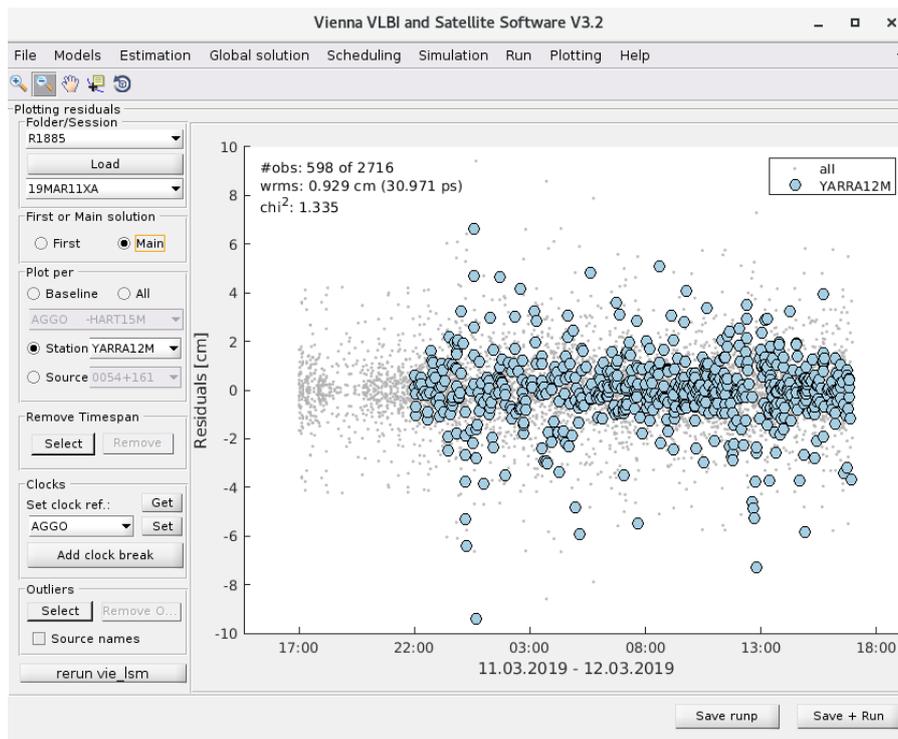
It is necessary to look for **clock breaks**. There are 2 clock breaks at the station YARRA12M (image below). Add the clock breaks as it was described in the exercise before. The clock breaks should now be listed in your OPT file. Make sure you selected “*use OPT files*” at “*File/Set input files*” and click “*Save + Run*” again to run another least squares adjustment with the additional clock breaks. After the process is finished you have to load the result in the *Plotting/Residuals* window again. Check if the clock breaks are now gone.



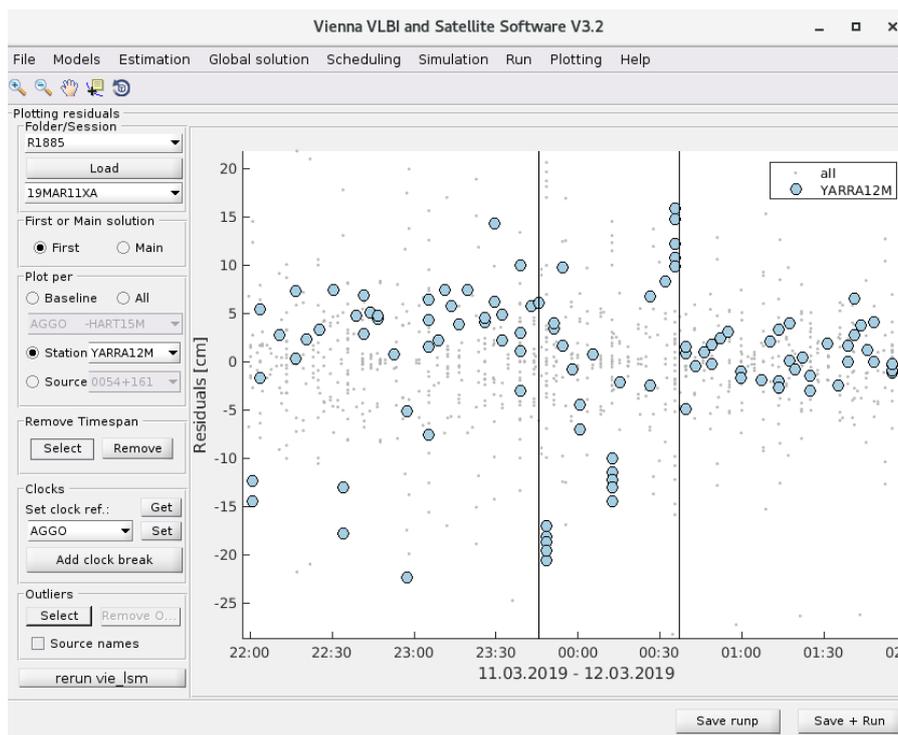
2.4 Exclude Observations

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 YARRA12M around midnight in the first and in the main solution (see images below). It is possible to exclude observations from a station for a specific time span.





To exclude these observation you should change the zoom in order to see the outliers nicely. Make sure to unclick the zoom button again. Now click on the *Select* button in the *Remove Timespan* Section on the left. You can select the outliers by pressing the mouse button at the start of the time span which you want to remove and hold the mouse button pressed down. When you now move your mouse two lines appear. These lines are marking the start and the end of the selected time span. In that way you can select the observations which should be removed. In the image below the lines marking the specific time span for removing the outliers is shown. The observations inside of the two lines will be removed. If you are satisfied you can now remove the outliers by clicking on the button *Remove* next to the *Select* button in the *Remove Timespan* Section and confirm that you want to remove these observations.



The timespan which will be excluded for the Station YARRA12M is now listed in the OPT file. Click “*Save + Run*” again to run another least squares adjustment with excluding these observations.

2.5 Set 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 station wise you can see that there are not that many observations for AGGO. So it would be a good idea to set the reference clock to a clock of a station which has a stable clock and a rather high number of observations. This can be done in the Section *Clocks* on the left. Select the station whose clock should be the reference clock in the drop down menu and click the *Set* button.

After the analysis the OPT file should contain the content as it is shown in the following image.



```
CLOCK REFERENCE:
WETTZELL
CLOCK BREAKS: 2
YARRA12M 58554.026418
YARRA12M 58554.537078
STATIONS TO BE EXCLUDED: 1
YARRA12M 58553.990231-58554.026391
BASELINES TO BE EXCLUDED: 0
SOURCES TO BE EXCLUDED: 0
STATIONS TO BE DOWN-WEIGHTED: 0
NO CABLE CAL: 0
```

2.6 Remove outliers

Check the residuals again at “*Plotting/Residuals*” and check if there are any obvious outliers. If you do not see any consider yourself lucky and relax. If there are outliers it is necessary to remove them as it is described in the previous exercise.

After removing the clock breaks, excluding observations from YARRA12M and removing the outliers the χ^2 is 1.201.

2.7 Output

It is again possible to have look at the estimated parameters, the data stored in the MATLAB structure and to create the SINEX file as it was described in the previous section.