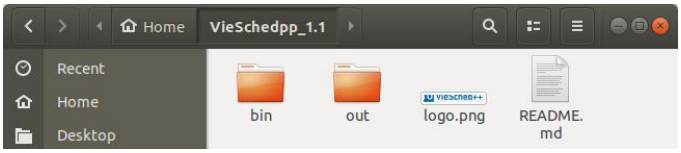
VieVS webinar – Scheduling and Simulations with VieSched++

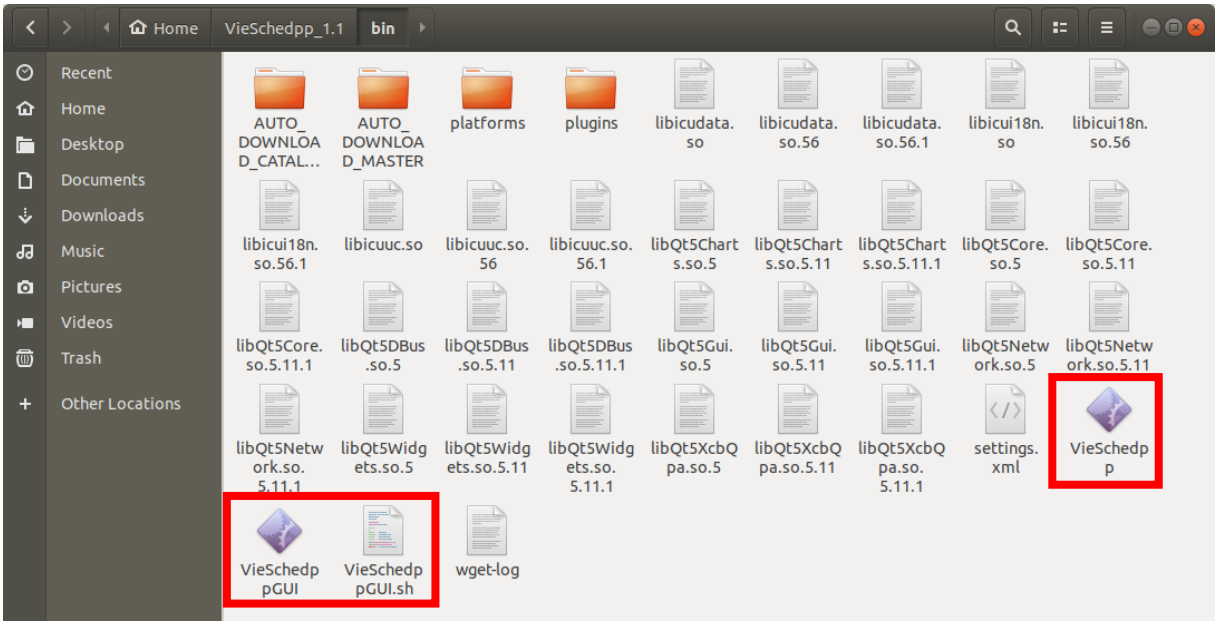
In this webinar we will explore the VieSched++ software and its capabilities to generate schedules and simulations. There are manuals that show you how to schedule an R1 or VGOS session[1]. In contrast to these "cookbooks", here, I want to focus more on **why** you should use the algorithm/parameter you will select and not only show you which should be selected.

Before we start, let's have a look at where we find all the necessary files.
If you installed VieSched++ using the Installers, you should see the following files in your install directory:



The "bin" folder includes all the binaries and the necessary catalog files while the "out" folder contains the generated schedules.

Inside the "bin" folder, you will find the executables "VieSchedpp" as well as "VieSchedppGUI". On Linux, you will find a shell script "VieSchedppGUI.sh" as well, this should be used to start the program.



Additionally, you can see the "AUTO_DOWNLOAD_CATALOGS" and "AUTO_DOWNLOAD_MASTER" folders. There, VieSched++ will store the most recent catalogs and master files. Do not edit any of these files here since changes will be overwritten the next time you start VieSched++.

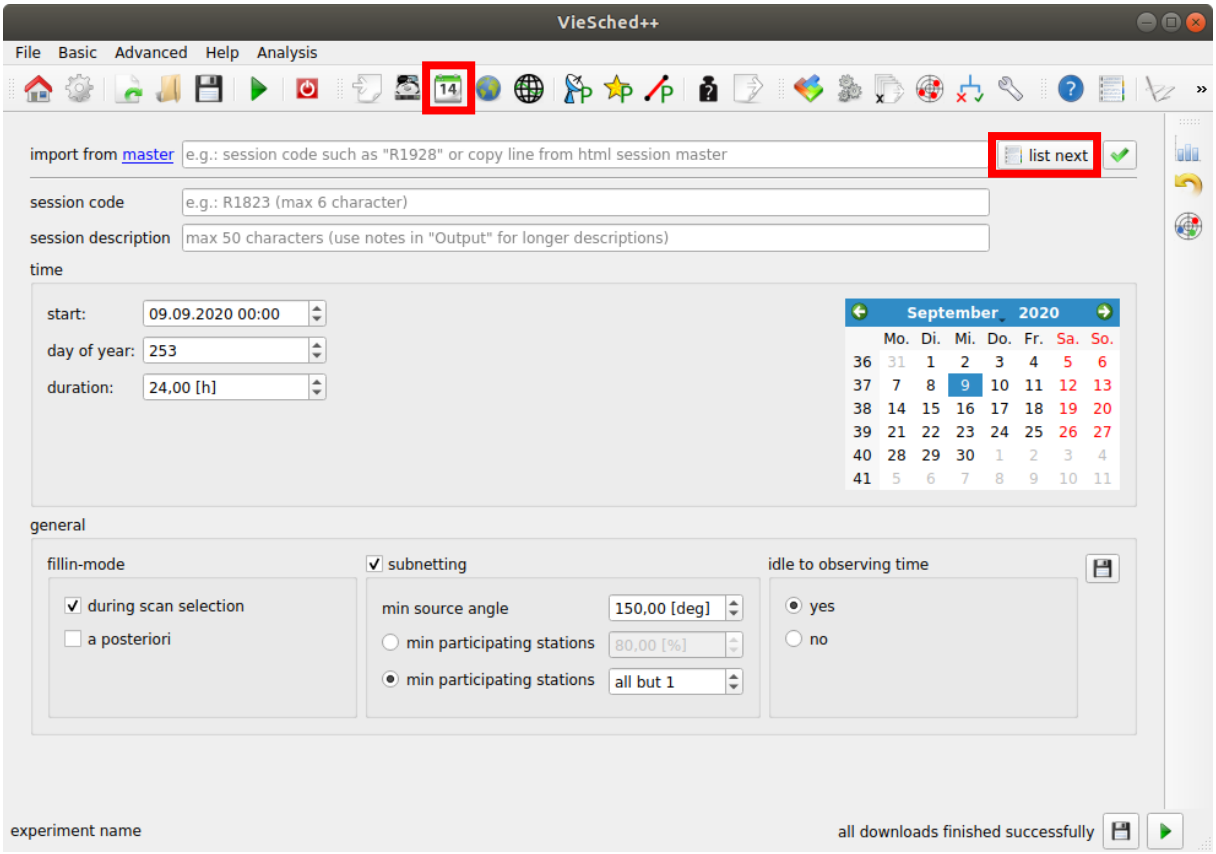
NOTE: It might be, that the automated download of the catalog files fails. This has to do with special cryptography libraries that are required to download files via https. If this is the case, you need to install a compatible version of OpenSSL on your computer. However, you can also ignore the automated downloading since this is only an optional feature and simply download the latest catalog files by yourself. If you have troubles on windows, I can send you the necessary libraries.

Now, let's finally start VieSched++ and generate our first schedule.

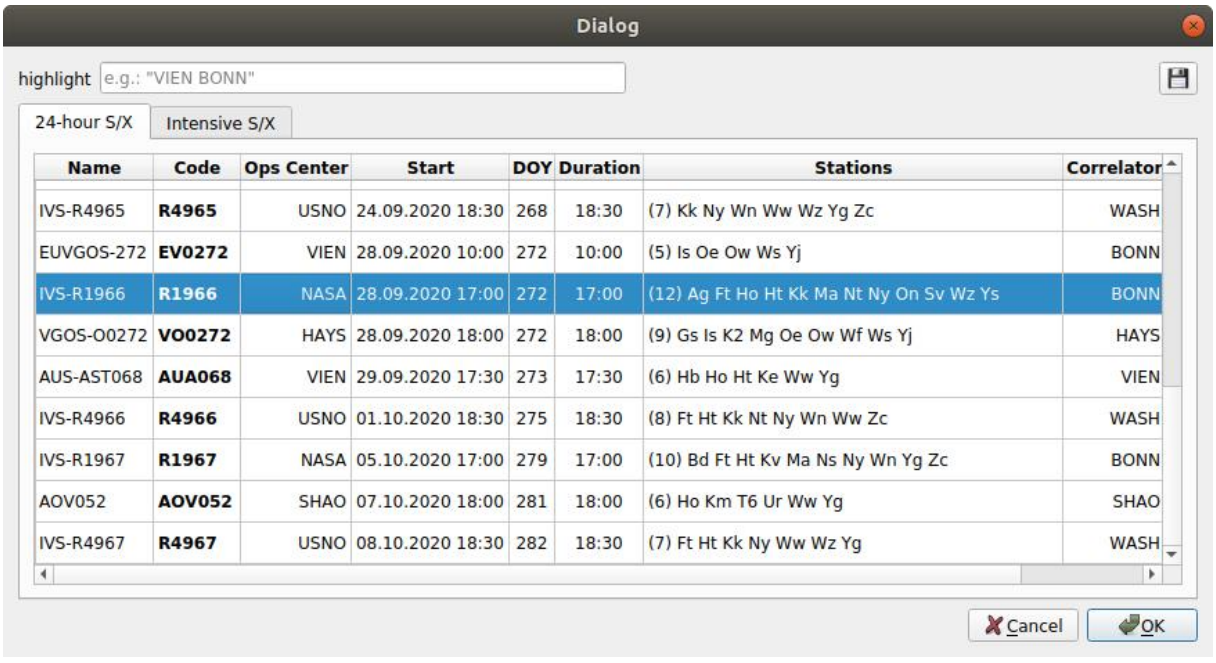
[1] https://vievswiki.geo.tuwien.ac.at/doku.php?id=public:vieschedpp:vieschedpp

Example 1: standard 24-hour session with a global network

For this demonstration, we will generate a schedule for one of the next R1 sessions, namely ***R1966***. Go to the "General" tab in the VieSched++ GUI.
Since we want to generate a schedule for a session listed in the IVS master, we can simply click on "list next" to see which sessions are starting next.

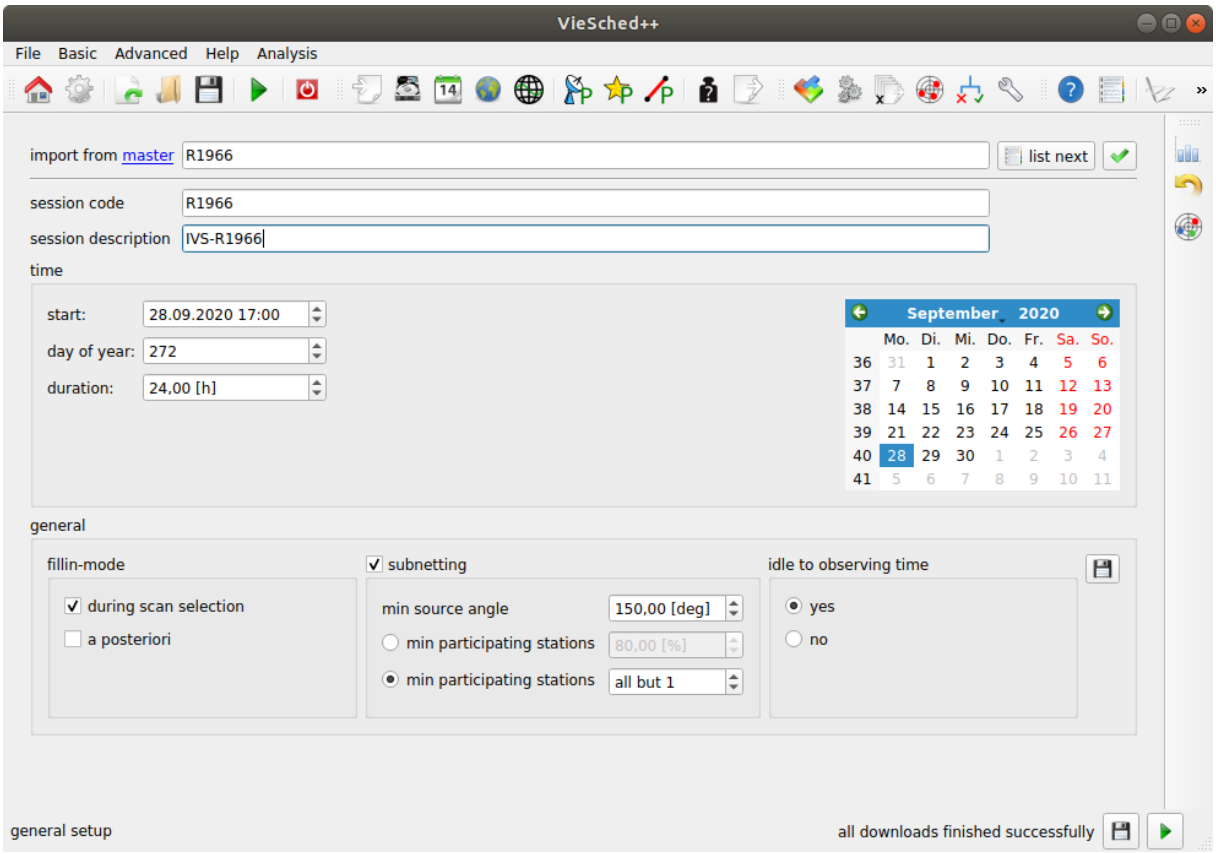


Here, you should be able to find the session R1966. Double-click it to load the settings.



Name	Code	Ops Center	Start	DOY	Duration	Stations	Correlator
IVS-R4965	**R4965**	USNO	24.09.2020 18:30	268	18:30	(7) Kk Ny Wn Ww Wz Yg Zc	WASH
EUVGOS-272	**EV0272**	VIEN	28.09.2020 10:00	272	10:00	(5) Is Oe Ow Ws Yj	BONN
IVS-R1966	**R1966**	NASA	28.09.2020 17:00	272	17:00	(12) Ag Ft Ho Ht Kk Ma Nt Ny On Sv Wz Ys	BONN
VGOS-O0272	**VO0272**	HAYS	28.09.2020 18:00	272	18:00	(9) Gs Is K2 Mg Oe Ow Wf Ws Yj	HAYS
AUS-AST068	**AUA068**	VIEN	29.09.2020 17:30	273	17:30	(6) Hb Ho Ht Ke Ww Yg	VIEN
IVS-R4966	**R4966**	USNO	01.10.2020 18:30	275	18:30	(8) Ft Ht Kk Nt Ny Wn Ww Zc	WASH
IVS-R1967	**R1967**	NASA	05.10.2020 17:00	279	17:00	(10) Bd Ft Ht Kv Ma Ns Ny Wn Yg Zc	BONN
AOV052	**AOV052**	SHAO	07.10.2020 18:00	281	18:00	(6) Ho Km T6 Ur Ww Yg	SHAO
IVS-R4967	**R4967**	USNO	08.10.2020 18:30	282	18:30	(7) Ft Ht Kk Ny Ww Wz Yg	WASH

Now, VieSched++ should have automatically inserted the correct session code, description, start time, duration, network and many other things for you.



Alternatively, you could have simply entered “R1966” in the field next to “import from master” and hit enter, or you could have selected everything manually.

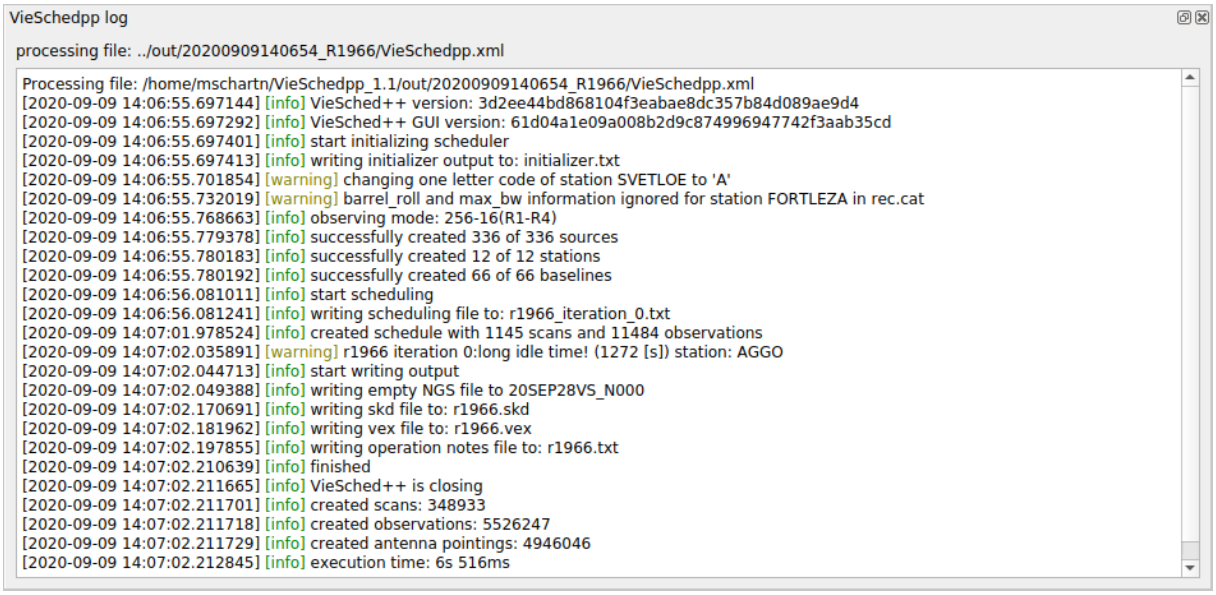
On this page, you can also change some of the general settings of the scheduling. For example, you can decide if you want to use **fillin-modes**, if you want to allow **subnetting** or if you want to transform **idle time to extra observation time** to reach a higher SNR.

You can also have a look at the **network** and the **source list** that is selected to see if everything is as expected. You can see which catalog files are used by browsing to the input tab. By default, VieSched++ is using the catalogs stored in the “AUTO_DOWNLOAD_CATALOGS” folder but you can always overwrite the default setting by saving your values using the button.

In general, you would also have to make sure that you are using the right **observing mode**. You can check the selected mode in the “Mode” tab. By default, we are using the “256-16(R1-R4)” mode. We can keep this for now.

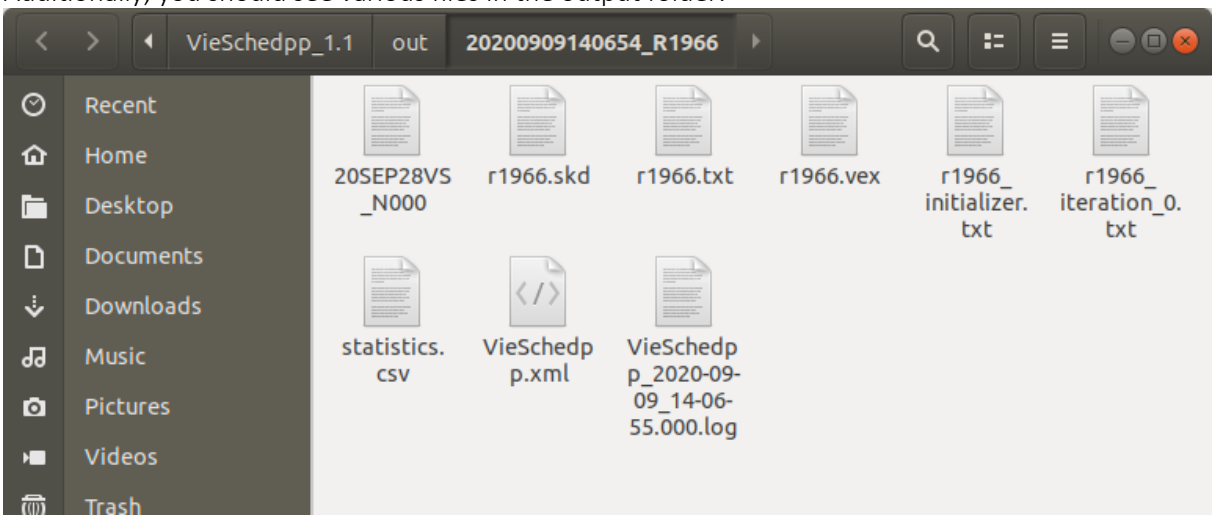
Finally, you can click on “run” to **start the scheduling**.
VieSched++ will first ask you if it should save the **xml file** containing all the GUI settings, click “Yes”.
Next, VieSched++ will ask you if it should open the folder with the results, click “Open”.

After some seconds, the scheduling should be finished and you should see the following **log file**:



In the log file, you can see that we get some warnings. The first two are not critical but the last one notes that there is a long idle time for station AGGO which we should keep in mind when we try to optimize the session further.

Additionally, you should see various files in the output folder:



- **r1966.skd**: this is the observation file that has to be sent to the participating stations.
- **r1966.txt**: this are the operation notes. This file is most important for the scheduler since it lists various interesting statistics and information.
- **r1966.vex**: this is another observation file that is typically used by the correlator
- **r1966_initializer.txt**: this file lists contains some human-readable general information about the session
- **r1966_iteration_0.txt**: this file is a human-readable log file from VieSched++.

We will now investigate how the schedule looks like and will first try to fix the most prominent issues that we find followed by a finer optimization of the parameters to increase the quality of the result.

Let's explore some of the files:

First, you can have a look at the **r1966_initializer.txt** file since it is the shortest. It lists if there were problems reading the input from the catalog files to create the necessary stations, sources and observing mode.
Next, we can explore the **r1966_iteration_0.txt** file. Here, you can see which scans are selected and get additional information. This is how a snapshot of this files looks like:

depth: 0									considered single scans 260, subnetting scans 112
scan: no0055 (id: 17398)									duration: 17:56:51 - 17:58:02
Source: 0920-397 (id: 128)									type: target subnetting scan
station	delay [s]	slew [s]	idle [s]	preob [s]	obs [s]	duration start - end	az [deg] start - end	unaz [deg] start - end	el [deg] start - end
HOBART26	6	122	0	10	71	17:56:51 - 17:58:02	115.1484 - 115.0112	115.1484 - 115.0112	34.7987 - 34.9958
KOKEE	6	52	70	10	71	17:56:51 - 17:58:02	160.5749 - 160.8029	520.5749 - 520.8029	24.0887 - 24.1795
scan: no0056 (id: 17399)									duration: 18:05:14 - 18:06:42
Source: 2000+472 (id: 281)									type: target subnetting scan
FORTLEZA	6	212	0	10	88	18:05:14 - 18:06:42	37.6132 - 37.5000	397.6132 - 397.5000	16.7863 - 17.0099
HART15M	6	13	38	10	63	18:05:14 - 18:06:17	355.5930 - 355.4086	-4.4070 - -4.5914	16.4063 - 16.3877
MATERA	6	42	9	10	65	18:05:14 - 18:06:19	24.7529 - 23.5179	744.7529 - 743.5179	82.3718 - 82.4560
NOTO	6	21	30	10	72	18:05:14 - 18:06:26	22.0741 - 21.1626	742.0741 - 741.1626	78.3774 - 78.4661
NYALES20	6	18	33	10	55	18:05:14 - 18:06:09	167.6562 - 167.9517	527.6562 - 527.9517	58.3610 - 58.3703
ONSALA60	6	33	18	10	88	18:05:14 - 18:06:42	145.8388 - 146.9672	505.8388 - 506.9672	78.5489 - 78.6585
SVETLOE	6	128	2	10	30	18:05:14 - 18:05:44	204.1167 - 204.4525	564.1167 - 564.4525	76.0866 - 76.0612
WETTZELL	6	11	40	10	35	18:05:14 - 18:05:49	103.0420 - 103.3651	463.0420 - 463.3651	84.0846 - 84.1777
YEBES40M	6	24	27	10	45	18:05:14 - 18:05:59	60.1632 - 60.0761	60.1632 - 60.0761	71.1458 - 71.2697

Additionally, this file report output from other algorithms that were selected. Here, you can see a snapshot of the "idle to observing time" algorithm:

scan: (id: 17399)					source: 2000+472 (id: 281)
station	increase [s]	new duration start - end	new obs [s]	old duration start - end	old obs [s]
HART15M	+67	18:05:14 - 18:07:24	130	18:05:14 - 18:06:17	63
MATERA	+101	18:05:14 - 18:08:00	166	18:05:14 - 18:06:19	65
NOTO	+39	18:05:14 - 18:07:05	111	18:05:14 - 18:06:26	72
NYALES20	+92	18:05:14 - 18:07:41	147	18:05:14 - 18:06:09	55
ONSALA60	+78	18:05:14 - 18:08:00	166	18:05:14 - 18:06:42	88
WETTZELL	+27	18:05:14 - 18:06:16	62	18:05:14 - 18:05:49	35

Finally, let's have a look at the most important file for optimizing scheduling, the operation notes file **r1966.txt**. In there, you can find various interesting statistics. First of all, let's explore how the stations spend their time:

	Ag	Ft	Ht	Ho	Kk	Ma	Nt	Ny	On	Sv	Wz	Ys	Avg
% obs. time:	52.84	54.68	60.04	43.64	52.53	59.42	46.75	61.62	66.50	34.89	61.63	53.08	53.97
% cal. time:	1.67	2.69	4.78	3.44	4.25	4.34	4.40	5.74	4.56	4.81	7.07	6.46	4.52
% slew time:	3.20	34.67	23.03	44.03	22.48	32.37	45.70	25.06	24.47	55.62	15.41	35.05	30.09
% idle time:	40.32	6.36	9.28	6.44	18.01	1.26	0.52	4.13	1.73	1.79	11.63	1.53	8.58
% field system:	1.00	1.61	2.87	2.06	2.55	2.60	2.64	3.44	2.74	2.89	4.24	3.88	2.71
total # scans:	145	233	414	298	369	376	381	497	395	417	613	559	391
# scans/hour:	6.04	9.71	17.25	12.42	15.38	15.67	15.88	20.71	16.46	17.38	25.54	23.29	16.31
total # obs:	517	1371	1758	557	1082	2313	2285	2378	2394	2335	2722	2664	1865
# obs/hour:	21.54	57.12	73.25	23.21	45.08	96.38	95.21	99.08	99.75	97.29	113.42	111.00	77.69
Avg scan (sec):	314.85	202.75	125.30	126.53	123.00	136.55	106.01	107.13	145.46	72.29	86.86	82.05	135.73
# Mk5 tracks:	16	16	16	16	16	16	16	16	16	16	16	16	
Total TB(M5):	1.39	1.44	1.58	1.15	1.39	1.57	1.23	1.62	1.75	0.92	1.62	1.40	1.42

You can see, that the idle time of Aggo is significantly longer than the idle time of the other stations. This is the case for several reasons: First, the sensitivity of Aggo is less than the sensitivity of the other stations. You can check this in the "Network" 🌍 tab in VieSched++ GUI. This is especially problematic, since we are only using a 256 Mbps mode and we did use the default maximum observation duration that is 600 seconds. Additionally, Aggo is located quite remotely. Its nearest stations is Fortleza which also has a lower sensitivity than the average station.

We can note, that we maybe want to try to **include Aggo better into the schedule**.

Next, let's have a look how many stations are typically observing together in a scan:

```
  Number of  2-station scans:    510 ( 44.39 %)
  Number of  3-station scans:    211 ( 18.36 %)
  Number of  4-station scans:     71 (  6.18 %)
  Number of  5-station scans:     49 (  4.26 %)
  Number of  6-station scans:     33 (  2.87 %)
  Number of  7-station scans:     38 (  3.31 %)
  Number of  8-station scans:     94 (  8.18 %)
  Number of  9-station scans:    131 ( 11.40 %)
  Number of 10-station scans:     12 (  1.04 %)
  Number of 11-station scans:      0 (  0.00 %)
  Number of 12-station scans:      0 (  0.00 %)
Total number of scans:          1149
Total number of obs:           11188
Total integrated obs-time:   1183773
Average obs-time:              105.8
```

You can see that we here have a very high number of two station scans. Typically you want to avoid having two station scans since you only get one baseline and thus only one observation out of these. Additionally, it is not possible to calculate closure delays from two station scans.

Note: in the upcoming release of VieSched++ v1.2 the default minimum number of stations per scan will be three. However, in the windows v1.1 release, this is already the case while in the Ubuntu release the minimum number of stations per scan is still two.

We can note that we would like to change the **minimum number of stations per scan to three** for this session.

Another interesting statistic in the operation notes file is the number of scans per 15 minutes. There are two tables, one showing the number of scans per station and one showing the number of scans per source. Let's first have a look at the number of scans per station:

Here, you can see that Aggo has again the lowest number of scans and observations. Additionally, you can see that there are two gaps, one for Kokee and one for Wettzell. This gaps were introduced since there are intensive sessions during this time with a higher priority than the R1 session. Since we did load the session information from the master schedule, VieSched++ automatically added the required station down time for you.

```
number of scans per 15 minutes:
#scans -> char: 1-9 -> '1'-'9'; 10 -> '0'; 11-36 -> 'A'-'Z'; 37-62 -> 'a'-'z'; 63+ -> '#'
.-----------------------------------------------------------------------------------------------------------------------------------------.
|          time since session start (1 char equals 15 minutes)                                       | #SCANS #OBS |   OBS Time [s]  |
| STATION |0   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18  19  20  21  22  23  |             |   sum  average |
|---------|+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|-------------|----------------|
|     AGGO|21 212112212211211122122111111111212 212112121212211213123421121112312222111212221212213222111212 |    145  517 | 45653    314.8 |
| FORTLEZA|332323212333412232213312312332142223423212222213322423422322422423322432223224422232231323233232|    233 1371 | 47241    202.8 |
|  HART15M|454545443534454353236455324635345355652843337525554648534543654554735633455553544643354544366243|    414 1758 | 51876    125.3 |
| HOBART26|545432323422362343314333224233364244342232234124325432423433443423523333343442423233353322335241|    298  557 | 37706    126.5 |
|    KOKEE|64453     12446343534642545134555256357245234244556554445674572424535333353445434362554444345542|    369 1082 | 45388    123.0 |
|   MATERA|533354235353534343434553634432644345554345523654554434544432533344462654443444344554244244345453 2|    376 2313 | 51343    136.6 |
|     NOTO|543445245343533443223444534332653445354564536733553524644542433534526554255544344342342533566544|    381 2285 | 40390    106.0 |
| NYALES20|765555346346544546645823754635665586767644554564456767555574644735726556543775766564755664565625|    497 2378 | 53243    107.1 |
| ONSALA60|644555336454524445444453543434463347535325532653554535545532633544725454433543636442553442454622|    395 2394 | 57456    145.5 |
|  SVETLOE|445443344455535454434655455535545445543553445535454455445254345553535453546545544545443456463 5|    417 2335 | 30143     72.3 |
| WETTZELL|87756     267576577778867677478865886787777688779788587686748677589577867777767687667867847876 65|    613 2722 | 53246     86.9 |
| YEBES40M|675575466576746556465655657747575567566676737756886756748664756657655685556766667565764685486455|    559 2664 | 45864     82.0 |
'-----------------------------------------------------------------------------------------------------------------------------------------'
```

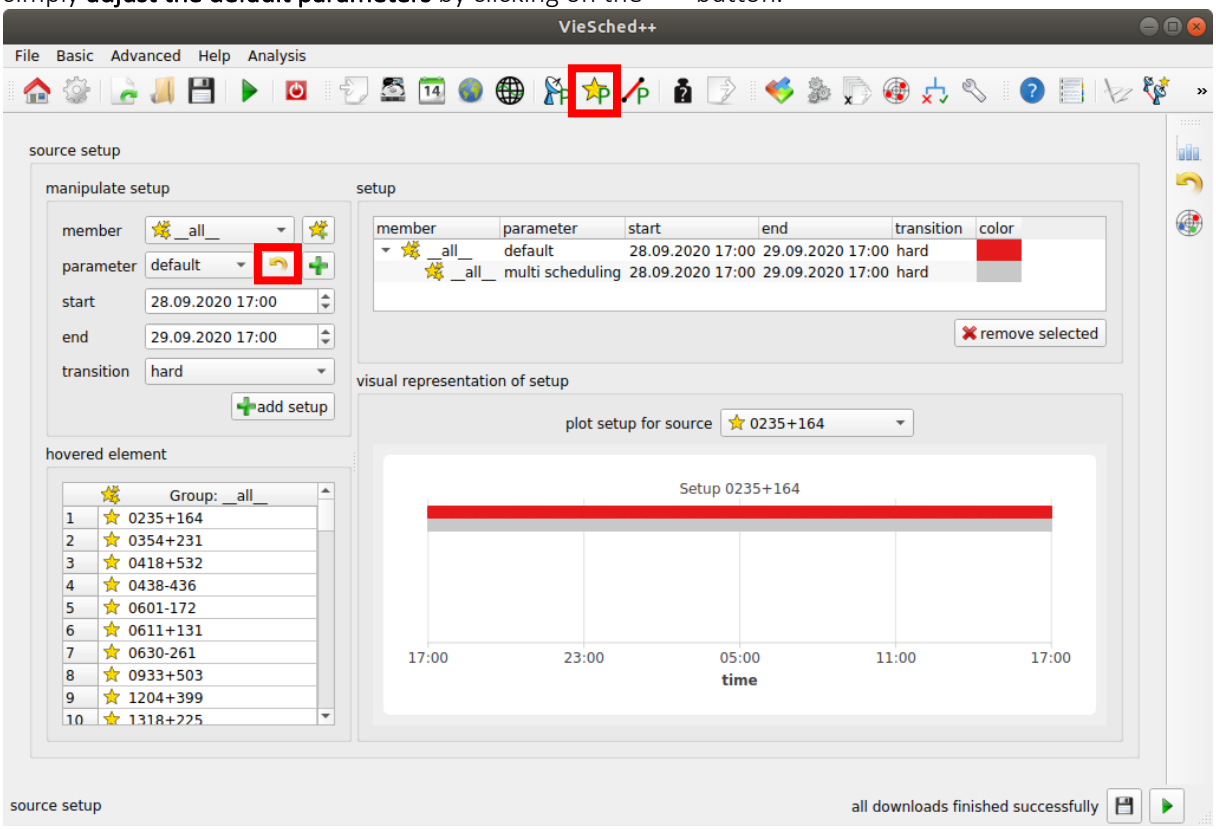
If you have a look at the number of scans per source, you can see that many sources are only scheduled for one scan and often times only with few observations. In general, it is best if every source is observed at least three times per session.

```
number of available sources:   336
number of scheduled sources:   157
number of scans per 15 minutes:
#scans -> char: 1-9 -> '1'-'9'; 10 -> '0'; 11-36 -> 'A'-'Z'; 37-62 -> 'a'-'z'; 63+ -> '#'
.-----------------------------------------------------------------------------------------------------------------------------------------.
|          time since session start (1 char equals 15 minutes)                                       | #SCANS #OBS |   OBS Time [s]  |
|  SOURCE |0   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18  19  20  21  22  23  |             |   sum  average |
|---------|+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|-------------|----------------|
| 0003-066|          1     1  1   1  1    1  1     1       1    1   1      1                               |     12   40 |  910     75.8 |
| 0008-264|                                                                                   1            |      1    1 |  138    138.0 |
| 0016+731| 1  1   1              1    1   1  1  1   1   1  1  1 1       1     1  1   1    1               |     18  312 | 1853    102.9 |
| 0017+200| 1               1         1     1  1                                    1  1  1            1   |      9  175 | 1821    202.3 |
| 0019+058|     1 1   1 1   1    1   1        1    1         1                                             |     10  115 |  976     97.6 |
| 0025+197|                                                                                         1      |      1    6 |  153    153.0 |
| 0048-427|                  1                                            1                                |      2    4 |  384    192.0 |
| 0059+581| 1   1  1      1 1 1        1  1      1  1    1    1   1  1        1            1     1   1     |     18  241 | 1469     81.6 |
| 0104-408| 1      1   1  1              1  1  1    1       1                     1      1             1   |     12   16 | 1374    114.5 |
| 0119+041|                                 1      1       1                                               |      3    8 |  216     72.0 |
| 0119+115|        1 1      1    1   1    1   1   1    1   1                                               |     10   75 | 1128    112.8 |
| 0131-522|  1   1              1   1          1                  1                              1         |      7   13 | 1476    210.9 |
| 0133+476|    1      1   1   1       1   1    1    1    1    1  1   1        1   1                     1  |     15  145 | 1219     81.3 |
| 0201+113|             1                                                                                  |      1    6 |  177    177.0 |
| 0202+319|   1    1   1    1 1  1   1  1  1  1   1   1          2   1              1        1    1  1  1  |     20  206 | 1819     91.0 |
| 0215+015|             1                                                              1           1      1|      4   31 |  764    191.0 |
| 0221+067|  1      1                                                                                      |      2   11 |  274    137.0 |
| 0229+131|                   1  1   1        1        1   1 1                            1                |      8  150 |  966    120.8 |
| 0235+164|                                                                                  1             |      1    3 |  157    157.0 |
| 0308-611|  1      1  1  1  1 1  1   1   1   1  1 1     1  1  1  1   1   1                          1 1   |     20   50 | 5537    276.9 |
| 0322+222| 1    1     1   1                   1  1    1           1                                       |      8  117 | 1520    190.0 |
| 0332-403|      1                                 1   1                                            1  1   |      5    5 |  420     84.0 |
|    CTA26|                                1           1 1                                                 |      3    8 |  138     46.0 |
| 0346-279|   1                                                                                          1 |      2    2 |  492    246.0 |
|  NRAO150|                   1    1    1 1         1           1            1      1             1    1   |     10   14 |  498     49.8 |
| 0400-319|                              1          1                                                      |      2    7 |  129     64.5 |
| 0402-362|         1   1       1   1     1       1 1  1  1         1                   1  1               |     12   29 | 1370    114.2 |
```

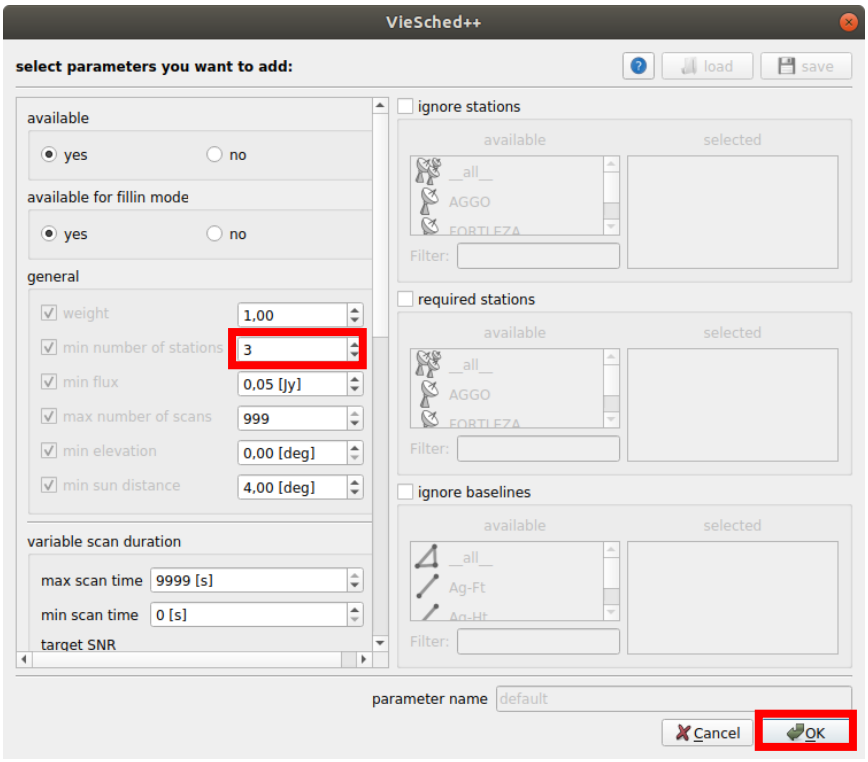
We can note, that we have to make sure that **every source is at least observed three times**.

Although looking at text files is a good way to explore your result, a visual inspection is often times better. You can use the **VieSched++ Analyzer** to explore the schedule as well. Go to the "Analyzer" tab and brows for the .skd file you have just generated. Now you can click on the "run session analyzer" button. Take some time to investigate the sky-coverage and the statistics. Use the sliders on the bottom to limit the display to a shorter duration.

Now let's start to correct the issues we have found.
First, we will change the **minimum number of stations required in a scan** in case the default option is two for your version of VieSched++. This can be done by changing the parameters. In VieSched++, there are parameters for each station, source and baseline. The minimum number of stations per scan parameter can be found at the source-parameters . Since we want to change this parameter in general, we can simply **adjust the default parameters** by clicking on the button.



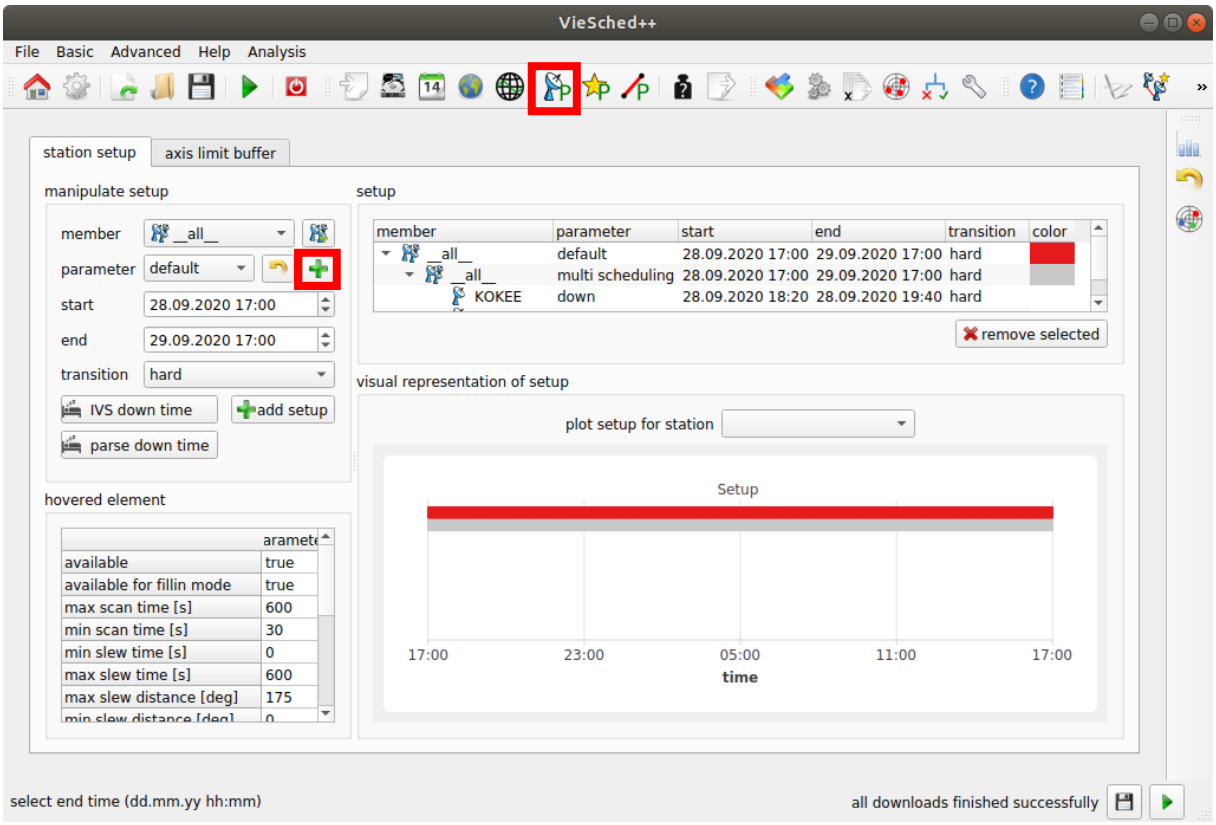
Take a minute to explore all the parameters you have here. You can find, that there is a "minimum number of stations" parameter. Change it from two to three.



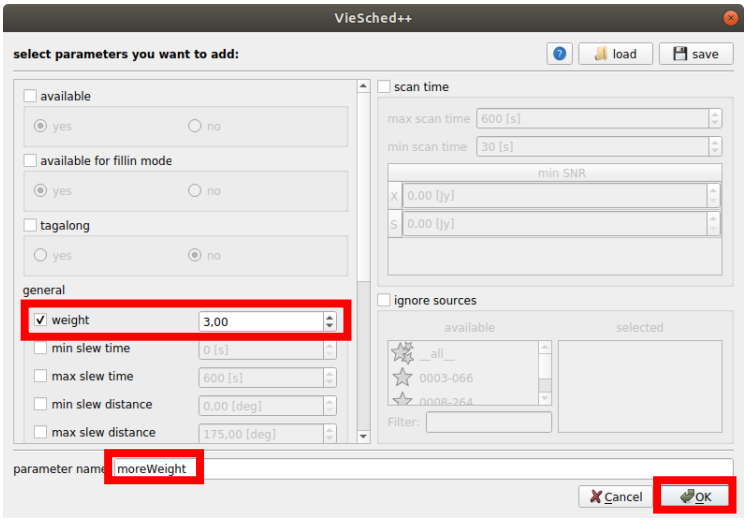
If it is already three you do not have to do anything at all.

Next, we want to extend the **maximum observation time slightly**. Note that I do not give a general recommendation to do this. The default maximum observation time should work fine in most cases. However, here we are only using a low observation rate of 256 Mbps in combination with low-sensitive stations, especially Aggo which is causing problems. Therefore, we should try if this helps us getting a better schedule. You can find the maximum observation time in the station-parameters. You can, again, change the default parameters and extend the maximum observation time to 900 seconds as done before. Please also take some time to explore the parameters you have in there as well.

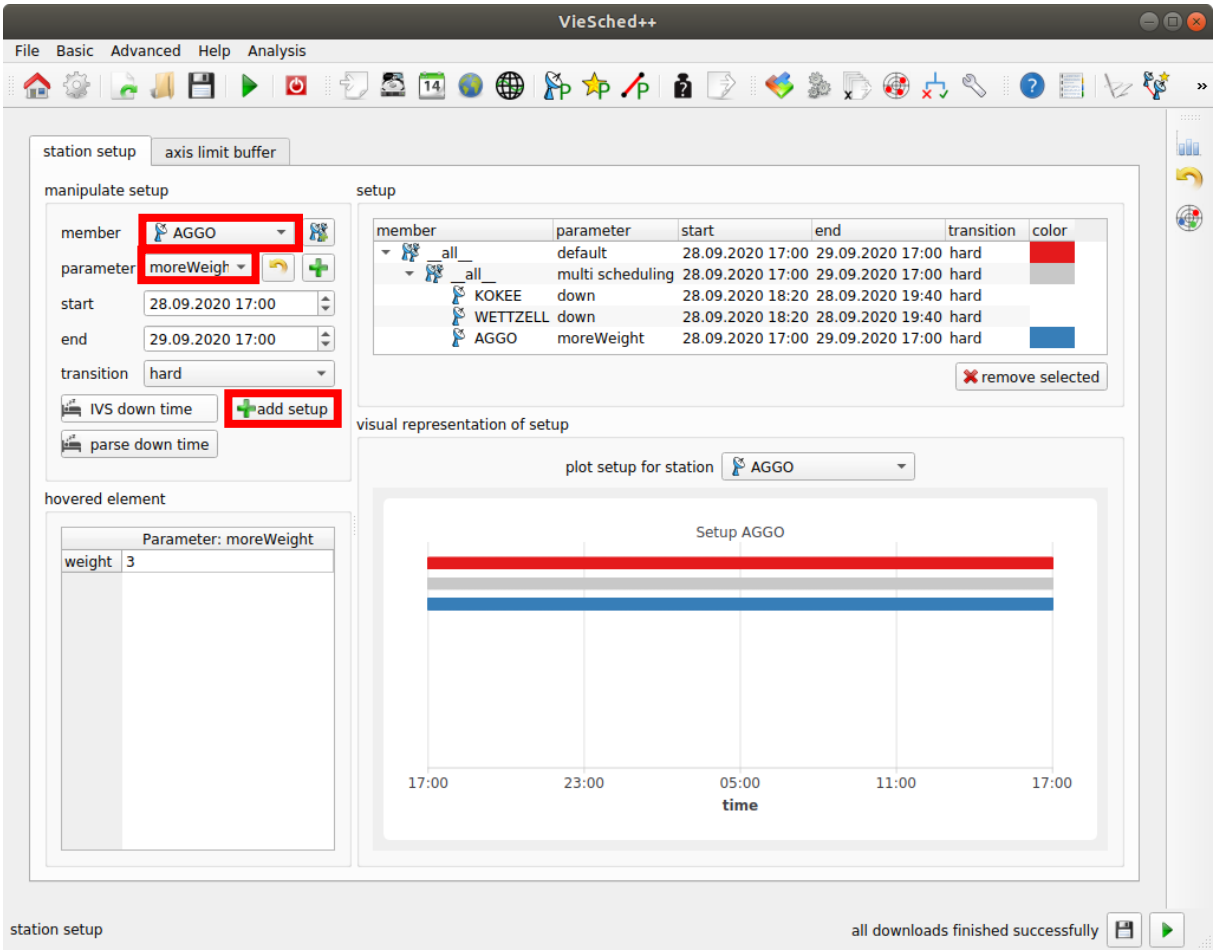
Additionally, we would like to increase the weight of Aggo during the scheduling. Therefore, we have to **define a new parameter** by clicking on the button ➕ next to parameter.



For this parameter, we would like to increase the "weight" from 1.0 to something higher, let's try 3.0. You have to give this parameter a name and click "ok" to store it.

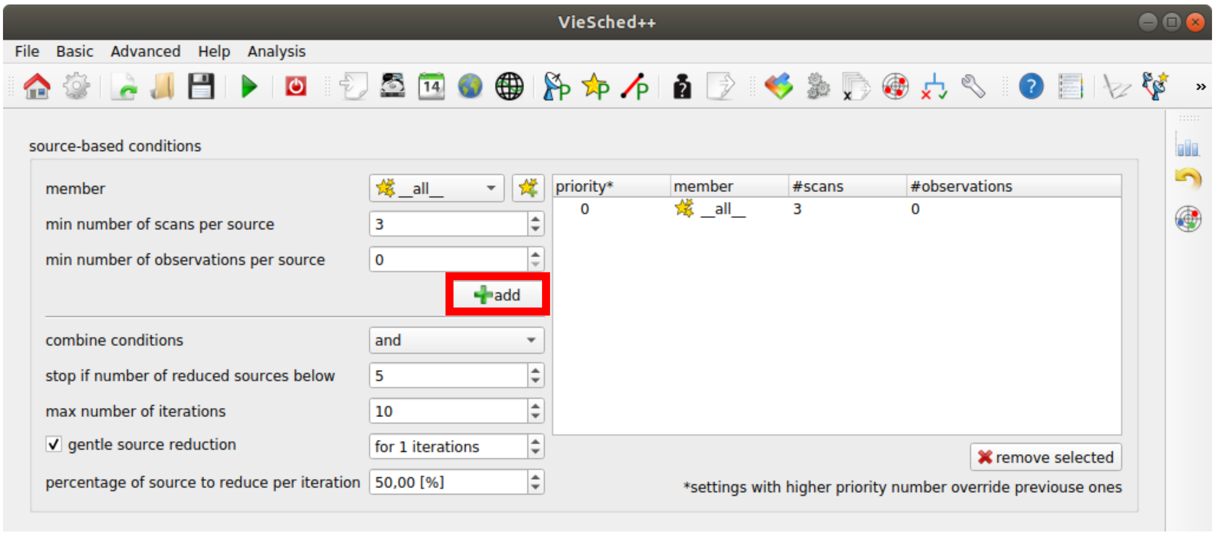


Now, we need to **assign this new parameter to a station**. In our case, we have to select AGGO as the member. Now we need to make sure that the new parameter is selected as well and that the time span covers the full session duration. Both should by default be the case. Now you can click on "➕ add setup" to apply the parameters to Aggo.

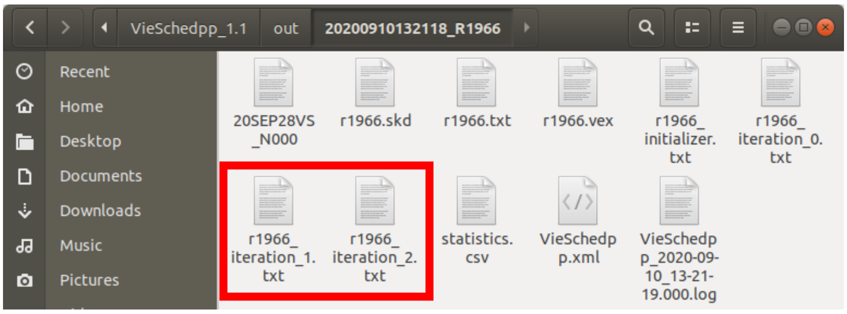


Now it is time to restart the scheduling by clicking on the "run" bottom and see if these changes helped us to solve some of the most prominent issues that we spotted. Have a look at the new operation notes file and see how things have changed.

One remaining issue, is that we want to make sure that **all sources are observed three times**. Therefore, go to the conditions tab in VieSched++.



You can now again click on “run” to restart the scheduling. If you have a look at the generated files, you will see that you now have more “r1966_iteration_X.txt” files.



If you open the “**r1966_iteration_0.txt**” file, you can see that at the very bottom of the file the following lines are written:

```
|                                                                                                         |
|                    checking optimization conditions... new schedule with reduced source list necessary |
|                                          creating new schedule with 108 sources                         |
|                                                                                                         |
|---------------------------------------------------------------------------------------------------------|
List of removed sources: (228)
    1519-294 1413+135 1417+273 1418-192 1424+366 1424-418 1428+370 1432+200 1441+252 1456+044 1502+036 1504+377
    1508-055 1519-273 1406-267 1520+437 1550-242 1557+032 1601+112 1602-115 1606-398 1615+029 1622-253 1623+578
     NGC6251 1645+224 1647-296 1651+391 1306+360 1056+212 1100+122 1104-445 1125+366 1133-032 1145+268 1156+295
    1204+399 1219+044 1226+373 1243-072 0008-264 1300+580 1656-075 1308+328 1308+554 1318+225 1327+504 1330+476
    1339-287 1342+662 1348+308 1349-439 1352-104 1354-152 1357+769 2254+074 2149+056 2155+312 2205+166 2208-137
    2209+236 2214+350 2215+020 2216+178 2227-399 2243+047 2250+194 2252-089 2254+024 2143-156 2300-683 2306-312
    2307+106 2309+454 2312-319 2325+093 2329-384 2335-027 2353+816 2356+385 2357-318 2358+189   IIIZW2 1909+161
    1659+399 1706-174 1718-649 1725+123 1736+324 1745+624 1746+470 1754+155 1758+388 1815-553 1823+689 1842+681
    1851+488 1255-177 1920-211 1952+138 1954-388 1958-179 2005-489 2013+163 2017+743 2106+143 2123-463 2127-096
    2141+175 2142+110 0627-199 0548+378 0346-279 0345+460 0556+238 0601-172 0602+673 0606-223 0611+131 0340+362
    0338-214 0347-211 0630-261 0632-235 0641+392 0656+082 0657+172 0332+078 0714+457 0723+219 0729+259 0738+491
    0406-127 0430+289 0434-188 0422-380 0422+004 0418+532 0415+398 0436-129 0414-189 0438-436 0442+389 0309+411
    0454+844 0506-612 0400-319 0358+210 0524+034 0530-727 0534-340 0536+145 0537-286 0354+231 0111+021 0920+390
    0134+311 0743+259 0933+503 0943+105 0115-214 0951+268 0958+346 1004-217 1004-500 0925-203 1013+127 1015+057
    0109+224 0055-059 0048-427 1027-186 0048-097 0047+023 1034-293 0035-252 0239+175 0237-027 0800+618 0804+499
    0227-369 0749+540 0912+029 0206+136 0747+185 0808+019 0821+394 0201+113 0151+474 0256-005 0847-120 0854-108
    0307+380 1053+815 2319+444 0332-403 0104-408 2000+148 0403-132    CTA26 2318+049 2126-158 2201+171 0131-522
    2144+092 1351-018 1608+243 1555+001 0613+570 1538+149 1806+456 1451-375 0718+793 1418+546 0743+277 0759+183
    0700-197 0823+033 0920-397 1213-172 1013+054 1144-379 1111+149 1015+359 1101+384 1059+282 1053+704 0437-454
```

This means, that VieSched++ will start a new scheduling iteration with a reduced number of sources. If you open “**r1966_iteration_1.txt**” you will read the following at the very top of the file:

```
Iteration number: 1
Total number of sources: 336
available source: (108)
    0003-066 0016+731 0017+200 0019+058 0025+197 0054+161 0059+581 0119+041 0119+115 0133+476 0202+319 0215+015
    0221+067 0229+131 0235+164 0308-611 0322+222  NRAO150 0402-362 0405-385 0420+022 0420-014 0446+112 0454-234
    0458-020 0506+101 0515+208 0529+483 0537-441 0544+273 0552+398 0642+449 0646-306 0648-165 0716+714 0727-115
    0736+017 0748+126 0805+410 0814+425 0827+243 0834-201    OJ287 0955+476 1030+415 1039+811 1040+244 1057-797
    1123+264 1124-186 1128+385 1144+402 1149-084 1212+171    3C274 1243-160 1244-255 1255-316 1324+224 1334-127
    1406-076 1417+385 1514+197 1520+319 1546+027 1606+106 1616+063 1617+229 1636+473  NRAO512 1639+230 1639-062
       DA426 1657-261 1705+018 1722+330 1726+455 1732+389 1741-038 1749+096 1751+288 1758-651 1759-396 1800+440
    1803+784    3C371 1846+322 1849+670 1908-201 1921-293 1923+210 1928+154 1929+226 1936-155 2000+472 2008-159
       3C418 2052-474 2059+034 2113+293 2214+241 2215+150    3C446 2227-088 2229+695 2255-282 2319+317 2355-106
not available because of optimization: (228)
    0008-264 0035-252 0047+023 0048-097 0048-427 0055-059 0104-408 0109+224 0111+021 0115-214 0131-522 0134+311
    0151+474 0201+113 0206+136 0227-369 0237-027 0239+175 0256-005 0307+380 0309+411 0332+078 0332-403    CTA26
    0338-214 0340+362 0345+460 0346-279 0347-211 0354+231 0358+210 0400-319 0403-132 0406-127 0414-189 0415+398
    0418+532 0422+004 0422-380 0430+289 0434-188 0436-129 0437-454 0438-436 0442+389 0454+844 0506-612 0524+034
    0530-727 0534-340 0536+145 0537-286 0548+378 0556+238 0601-172 0602+673 0606-223 0611+131 0613+570 0627-199
    0630-261 0632-235 0641+392 0656+082 0657+172 0700-197 0714+457 0718+793 0723+219 0729+259 0738+491 0743+259
    0743+277 0747+185 0749+540 0759+183 0800+618 0804+499 0808+019 0821+394 0823+033 0847-120 0854-108 0912+029
    0920+390 0920-397 0925-203 0933+503 0943+105 0951+268 0958+346 1004-217 1004-500 1013+054 1013+127 1015+057
    1015+359 1027-186 1034-293 1053+704 1053+815 1056+212 1059+282 1100+122 1101+384 1104-445 1111+149 1125+366
    1133-032 1144-379 1145+268 1156+295 1204+399 1213-172 1219+044 1226+373 1243-072 1255-177 1300+580 1306+360
    1308+328 1308+554 1318+225 1327+504 1330+476 1339-287 1342+662 1348+308 1349-439 1351-018 1352-104 1354-152
    1357+769 1406-267 1413+135 1417+273 1418+546 1418-192 1424+366 1424-418 1428+370 1432+200 1441+252 1451-375
    1456+044 1502+036 1504+377 1508-055 1519-273 1519-294 1520+437 1538+149 1550-242 1555+001 1557+032 1601+112
    1602-115 1606-398 1608+243 1615+029 1622-253 1623+578  NGC6251 1645+224 1647-296 1651+391 1656-075 1659+399
    1706-174 1718-649 1725+123 1736+324 1745+624 1746+470 1754+155 1758+388 1806+456 1815-553 1823+689 1842+681
    1851+488 1909+161 1920-211 1952+138 1954-388 1958-179 2000+148 2005-489 2013+163 2017+743 2106+143 2123-463
    2126-158 2127-096 2141+175 2142+110 2143-156 2144+092 2149+056 2155+312 2201+171 2205+166 2208-137 2209+236
    2214+350 2215+020 2216+178 2227-399 2243+047 2250+194 2252-089 2254+024 2254+074 2300-683 2306-312 2307+106
    2309+454 2312-319 2318+049 2319+444 2325+093 2329-384 2335-027 2353+816 2356+385 2357-318 2358+189   IIIZW2
```

This confirms that this schedule is now generated with only 108 sources left.

If you have a look at the new operation notes file r1966.txt, you can see that we have now scheduled a lower number of different sources:

```
number of available sources:   336
number of scheduled sources:   77
number of scans per 15 minutes:
.-------------------------------------------------------------------------------------------------------------------------------------------------------.
|          time since session start (1 char equals 15 minutes)                                                                 | #SCANS #OBS |   OBS Time [s] |
|  SOURCE |0   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18  19  20  21  22  23  |             |   sum  average |
|---------|---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|-------------|----------------|
| 0003-066|      1      1     1  1  1     1  1 1   1                                                        |      9   91 |   701     77.9 |
| 0016+731|          1 1   1     1  1        1    1      1        1    1      1              1         1|     13  185 |  1322    101.7 |
| 0017+200|                                                                    1   1       1     1   1  |      5   21 |  1635    327.0 |
| 0019+058|   1   1      1   1      1    1    1 1      1                                              |      9  210 |  3639    404.3 |
| 0054+161| 1                                                                        1   1      1  1  1  |      6   18 |  4378    729.7 |
| 0059+581|   1                          1 1     1  1  1  1  1  1   1        1     1        1    1     2|     16  184 |  1695    105.9 |
| 0119+115|    1  1                  1  1  1  1   1       1                                              |      8  127 |  3113    389.1 |
| 0133+476|                                          1    1 1          1   1       1      1           |      7   63 |  1019    145.6 |
| 0202+319|             2   1            1     1  1  1  1  1    1  1        1                    1   1|     14  302 |  5072    362.3 |
```

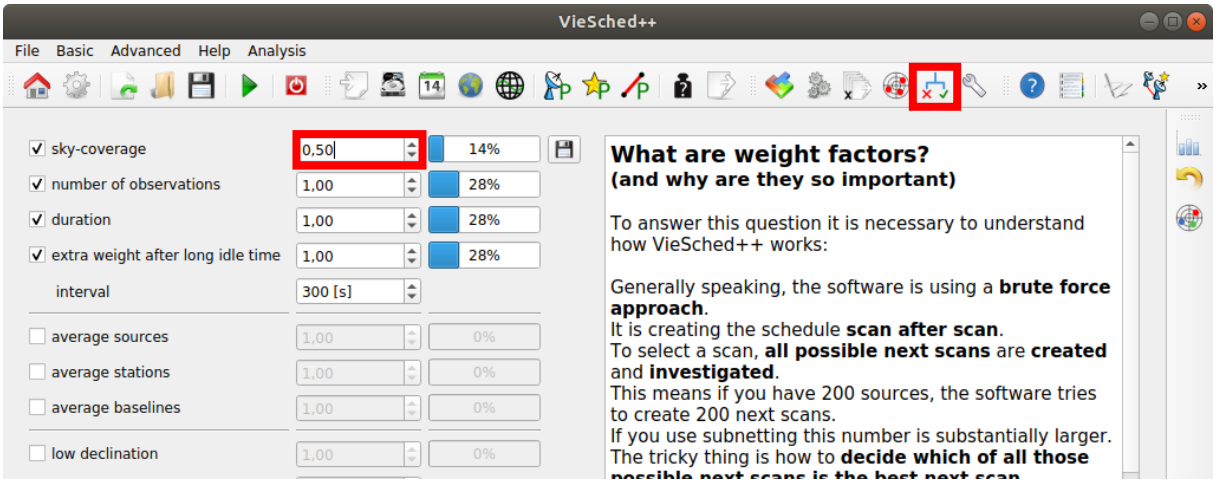
Now we probably took care of the most obvious issues in the schedule.

Next, we can start to **fine-tune the scheduling**. The most important factors during scheduling are the so-called **weight factors**. So far, we simply used to default values which put an equal weight on the four most important optimization conditions:

- sky-coverage
- number of observations per scan
- scan duration
- mitigation of long idle times

We can now go to the “Weight factor” tab and change one of the weight factors and see what happens:

Let’s decrease the sky-coverage weight factor to 0.5 and restart a new schedule .



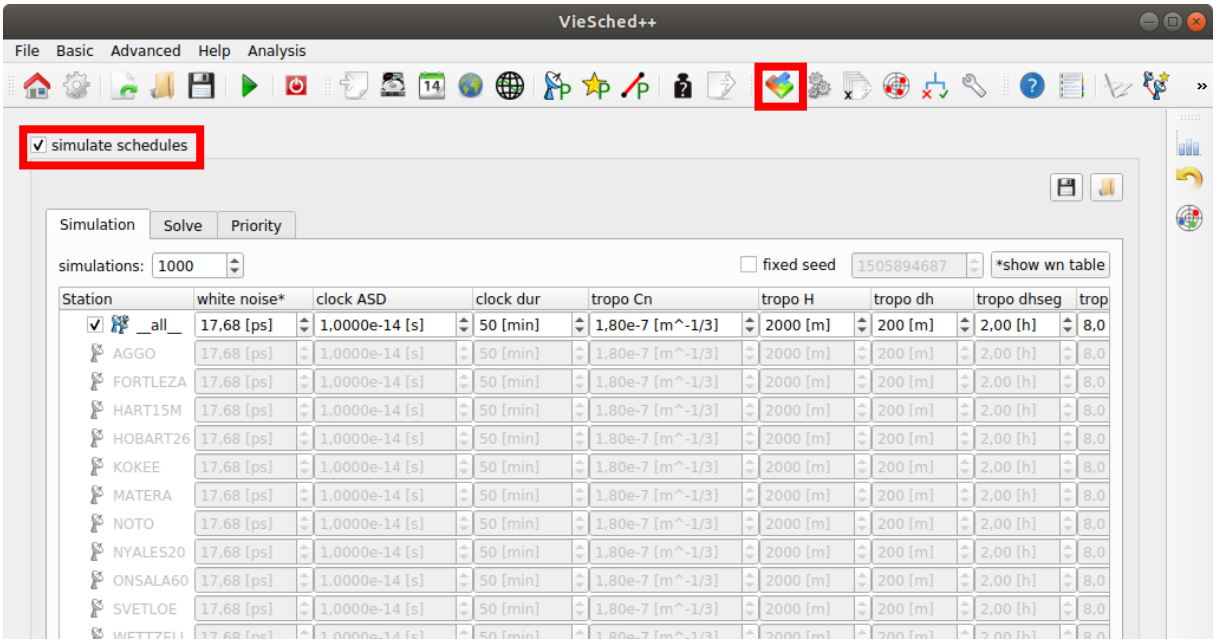
If restart the scheduling by clicking on you will get a different schedule. The big question is:

How can we determine which schedule is better and which parameters should I finally use?

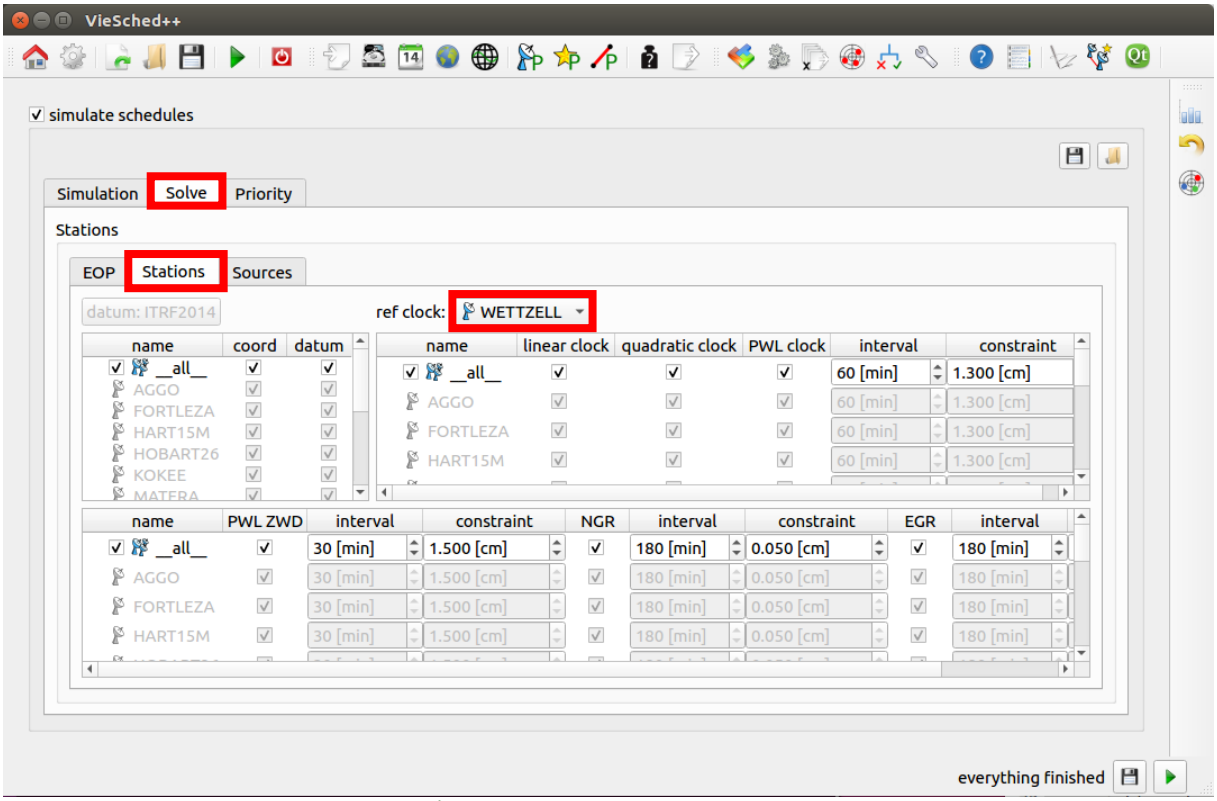
This can be answered by using the **multi-scheduling tool** together with **simulations**.

Let's first have a look on how we can **simulate our schedules**:

First, you have to browse to the "Simulation" tab and check "simulate schedules". Here, you should take some time to explore which simulation parameters will be used. You can either use the same parameters for all stations (the default option) or specify individual parameters per station. Please note that by default, you will execute 1000 simulation runs per schedule.

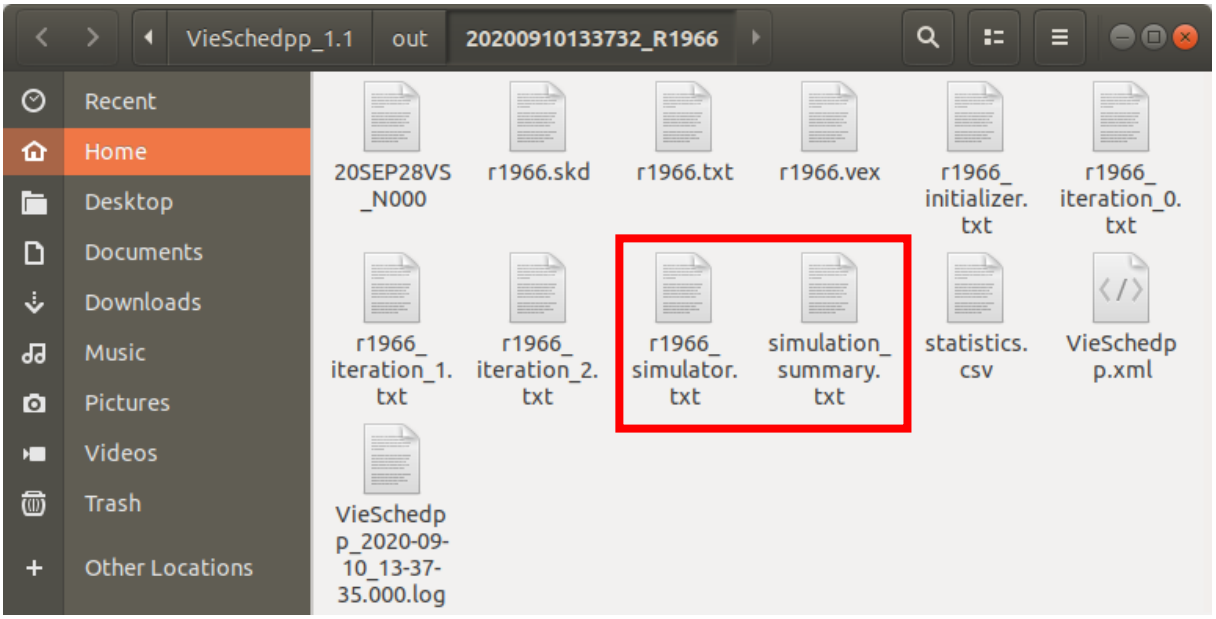


If you have a look at the “Solve” tab, you can have a look at which parameters will be estimated during the least-squares adjustment. One thing you might want to change is to set a different station than Aggo for the reference clock. We will do this, since we know that Aggo may cause problems during the scheduling and we will probably not have a lot of observations with Aggo. In this example, I will define WETTZELL as the reference station for the clock.
Note: In the upcoming release of VieSched++ you do not have to define a reference clock manually



Now you can restart the scheduling  .

This time, you should get two additional files, namely r1966_simulator.txt and simulation_summary.txt.



Let's first have a look at the **r1966_simulator.txt** file. In this file, you will get an overview of all the parameters you have selected for simulation and the least squares-adjustment. Additionally, it lists some more output from the adjustment including the mean formal errors and repeatabilities of all estimated parameters.

Probably more important is **simulation_summary.txt** file. This file summarizes the most important parameters. This is a snapshot of how the file might look like for you:

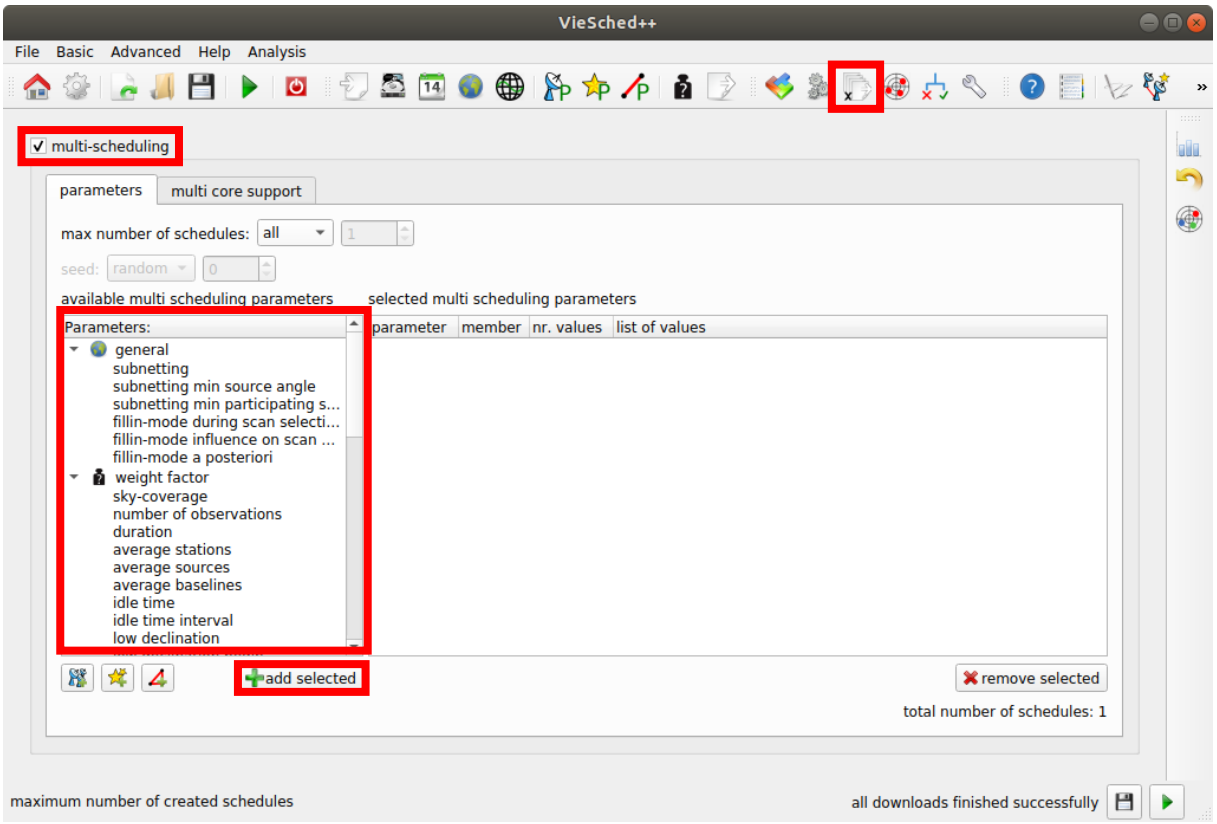
```
mean formal errors:
.-------------------------------------------------------------------------------------------------------------------------------------------------.
|   v   |  score  |    #obs    |     XPO    |     YPO    |    dUT1    |    NUTX    |    NUTY    |    AGGO    |  FORTLEZA  |   HART
|-------|---------|------------|------------|------------|------------|------------|------------|------------|------------|-------
|     0 |  0.0000 |       8541 |    54.2487 |    49.4123 |     3.7320 |    24.5925 |    24.2923 |    10.9867 |     9.1396 |      5.
'-------------------------------------------------------------------------------------------------------------------------------------------------'

repeatability:
.-------------------------------------------------------------------------------------------------------------------------------------------------.
|   v   |  score  |    #obs    |     XPO    |     YPO    |    dUT1    |    NUTX    |    NUTY    |    AGGO    |  FORTLEZA  |   HART
|-------|---------|------------|------------|------------|------------|------------|------------|------------|------------|-------
|     0 |  0.0000 |       8541 |   103.6478 |    86.8548 |     6.6516 |    43.9676 |    44.6949 |    18.9226 |    15.5118 |     11.
'-------------------------------------------------------------------------------------------------------------------------------------------------'
```

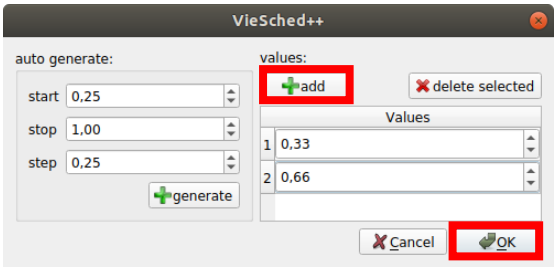
As you can see, you get the information about the estimated mean formal errors for the earth orientation parameters as well as for the 3d station coordinates.

Since we die only generate one schedule, the tables only list one value. Now it is time to change this by using the **multi-scheduling tool**.

First, browse to the multi-scheduling page and enable multi-scheduling. Next, you have to select one of the parameters that you want to experiment with. The most important factors that need to be optimized are the weight factors, especially: sky-coverage, number of observations, duration and idle time. Select one of the parameters and click on "add selected".



A new window should appear where you can select the values that should be tested. You can add the values manually, by clicking on the "add" button or you can generate some values using the start, stop and step parameters. After you added the values you want to test, you can click on "Ok" to store the values.

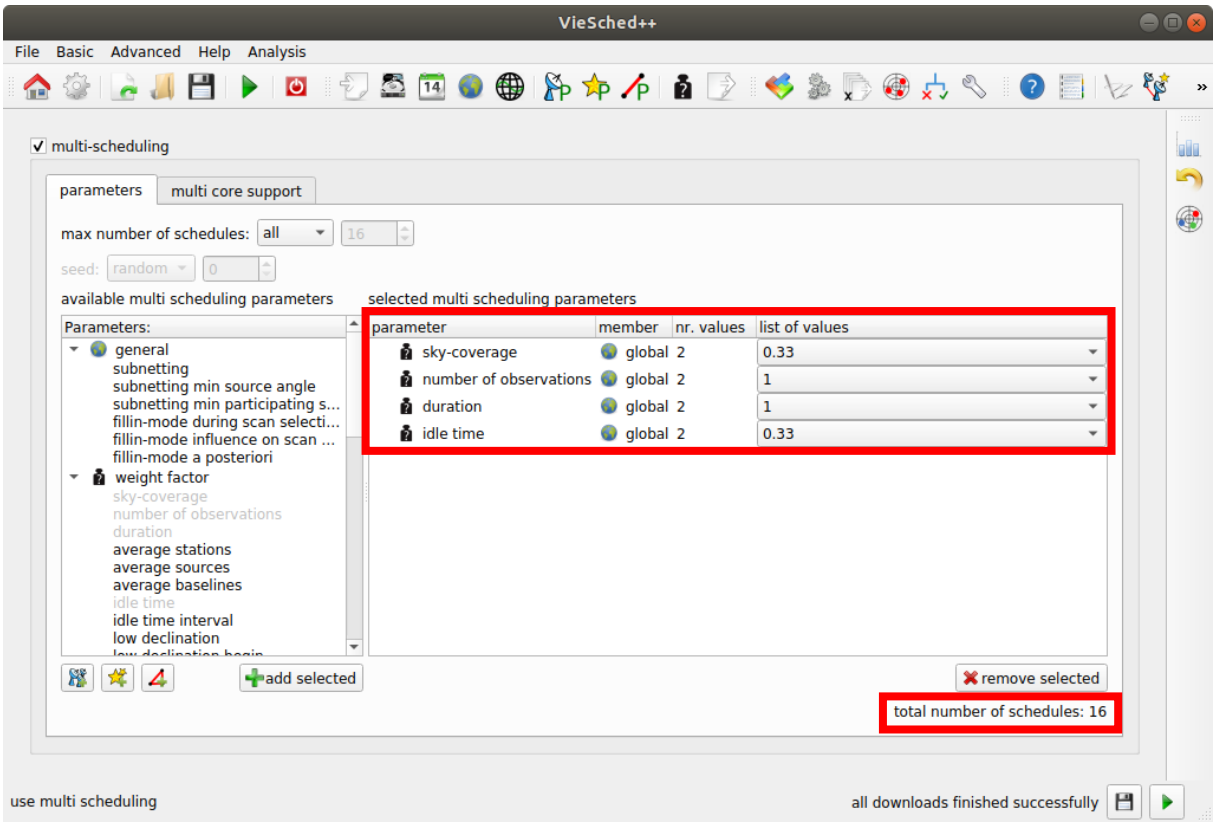


For this demonstration, you should select the following parameters and values:

- duration: 0.66, 1.00
- number of observations: 0.66, 1.00
- sky-coverage: 0.33, 0.66
- idle time: 0.33, 0.66

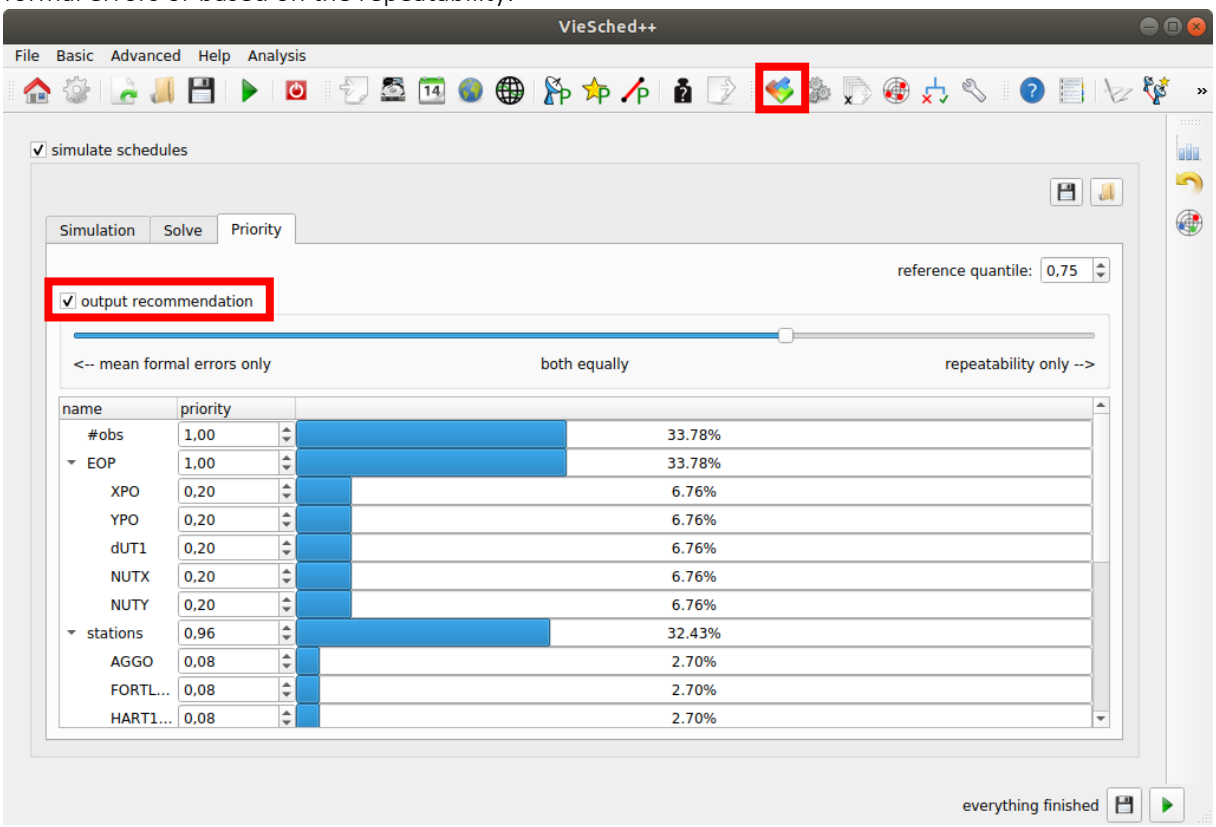
If you select parameters and assign values to those, VieSched++ will perform a grid-wise combination between all the selected values of the parameters and will generate different schedules using the combined values.

Note that VieSched++ should now generate a total of 16 schedules. This process is quite efficient since it will run in parallel on all of your available CPUs.
In reality, it might be advantageous to test more than two values per parameter (e.g.: three or four) but you need to be careful not to select too many parameters since this would generate too many schedules.
Note: in the next version of VieSched++, some reasonable pre-defined values will be suggested to you.



Additionally, we can use VieSched++ to help us **decide which schedule is the best for our session**. Therefore, go back to the simulations and select to the "Priority" tab. Here, you should click on "output recommendation". (**Note:** in the next release of VieSched++ this option will always be selected by default.)
On this page, you can define how important specific parameters are for your session. You can select certain earth orientation parameters or station coordinates as well as the number of observations.

Although it might not be a direct goal of your session, I would always recommend to also select a **high number of observations** as a primary goal of the session by giving it a high weight since in reality, a high number of observations correlates well with the actual precision of the geodetic parameters and you can never be sure that your simulations match reality well enough.
Additionally, you can select if the quality of the schedule should be determined based on the mean formal errors or based on the repeatability.

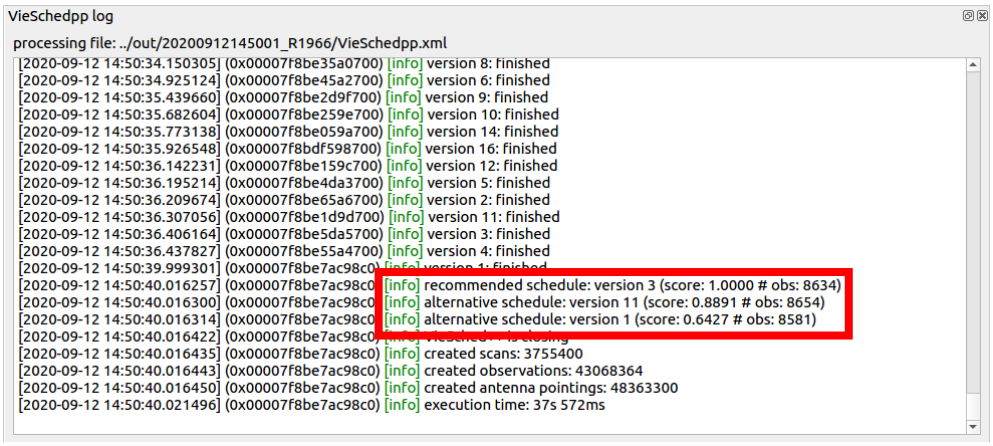


Now you can restart the scheduling by clicking on " run" again.

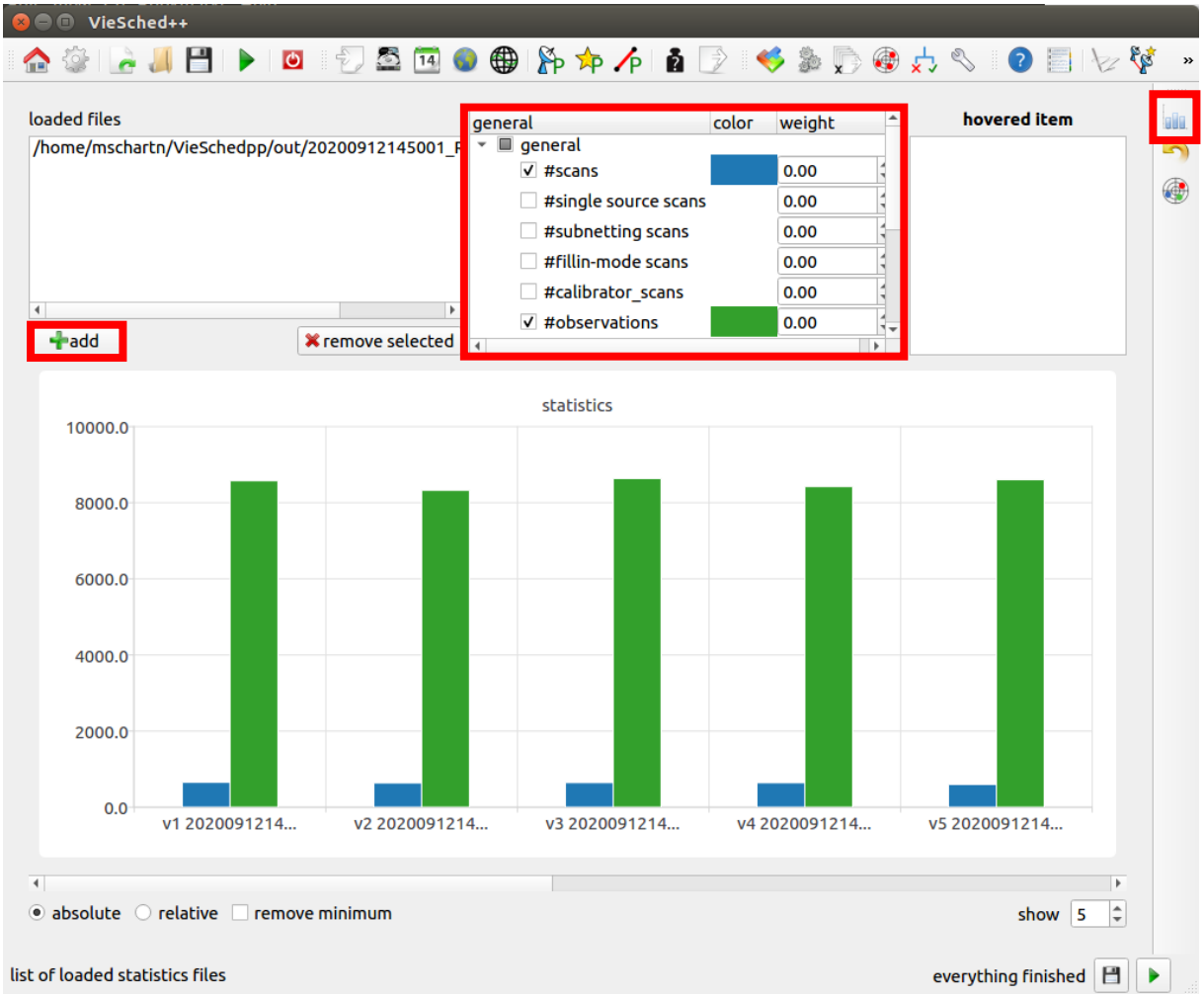
If you now have a look at your output folder, you should see that there are a lot more files generated as before. You should also notice, that all files have a new suffix such as "r1966_v001.skd". The "_v001" indicates that this schedule was generated using the first version of the multi-scheduling parameters.
If you open one of the operation notes files, such as "r1966_v001.txt" you can see which parameters were used, for example:

```
=============================================================
 Schedule was created using multi scheduling tool
    version 1
    weight sky-coverage 0.33
    weight number of observations 0.67
    weight duration 0.67
    weight idle time 0.33
=============================================================
```

If you have a look at the generated log file, you should see that VieSched++ suggests one version to you based on the settings you selected in the simulation, "Priority" tab.



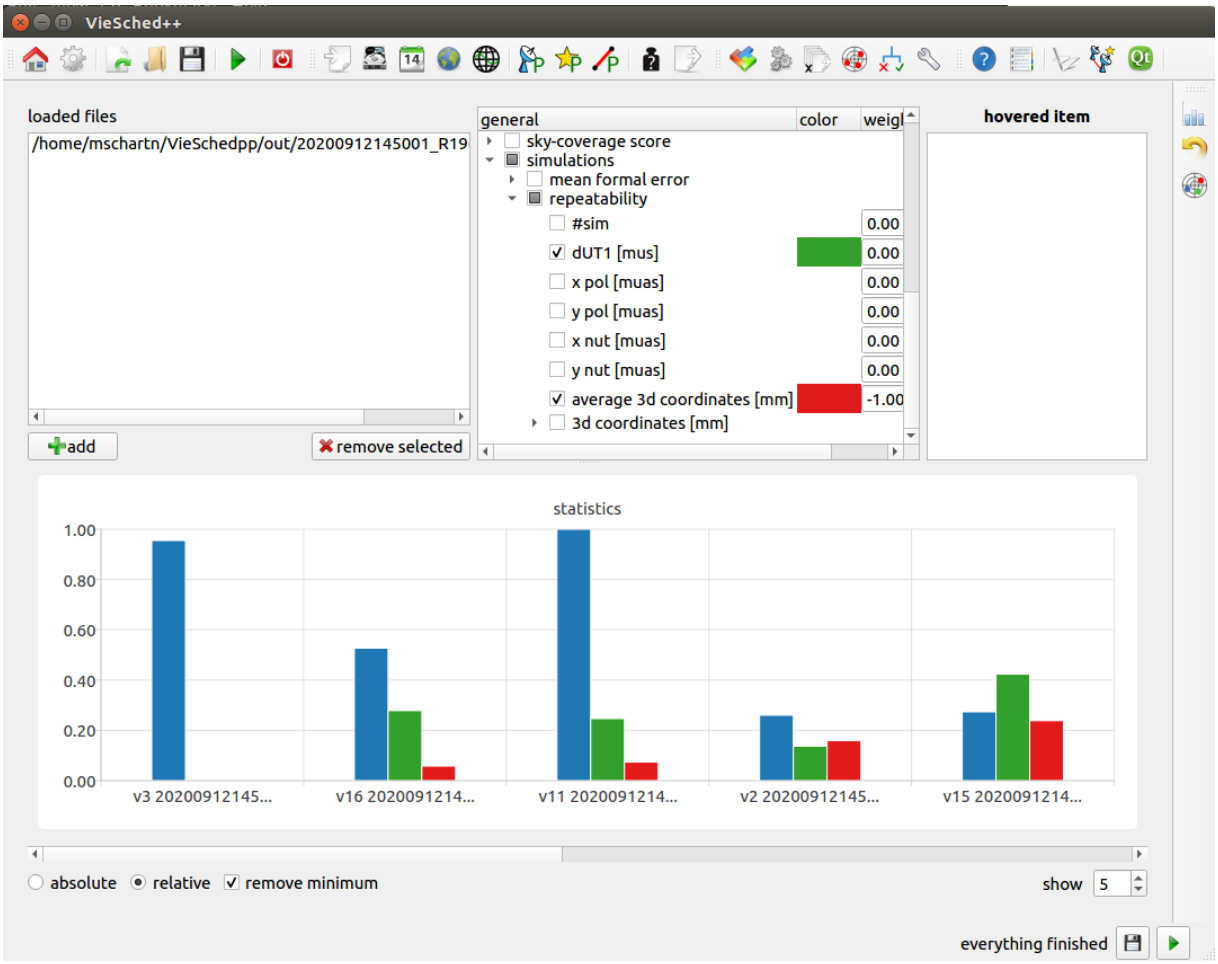
However, this recommendation follows very basic rules and you probably want to select the most promising schedule more sophisticated.
There are multiple ways how you can do this. You can either write an external tool to compare the schedules and select the best ones. If you choose this approach, notice that on every run, VieSched++ will generate a "statistics.csv" file that contains a very large number of interesting statistics and information. Since this is a simple CSV file, you can easily import and process it using Python (Pandas), Matlab, Excel or any other software you like.
Additionally, you can also use the **VieSched++ statistics tool** to view the content of the file.
Therefore, go to the statistics tab in VieSched++ and add a statistics.csv file by clicking on the "add" button.



In the middle field, you can now see all the available statistics and you see a graphical visualization of their values on the bottom. You can select parameters by checking them in the middle-top field. By default, the number of scans and number of observations are pre-selected. You can see that the number of scans are painted blue and the number of observations are painted green.

Additionally, you can add a weight to the parameters to sort the different versions. The sorting is based on the value of the parameter times their weight. You should take some time to play around with the options you have on this page to properly understand what is going on. Since the different parameter values have different orders of magnitude, it is possible to change the absolute view of the values to a relative view by changing the radiobutton on the bottom from absolute to relative.

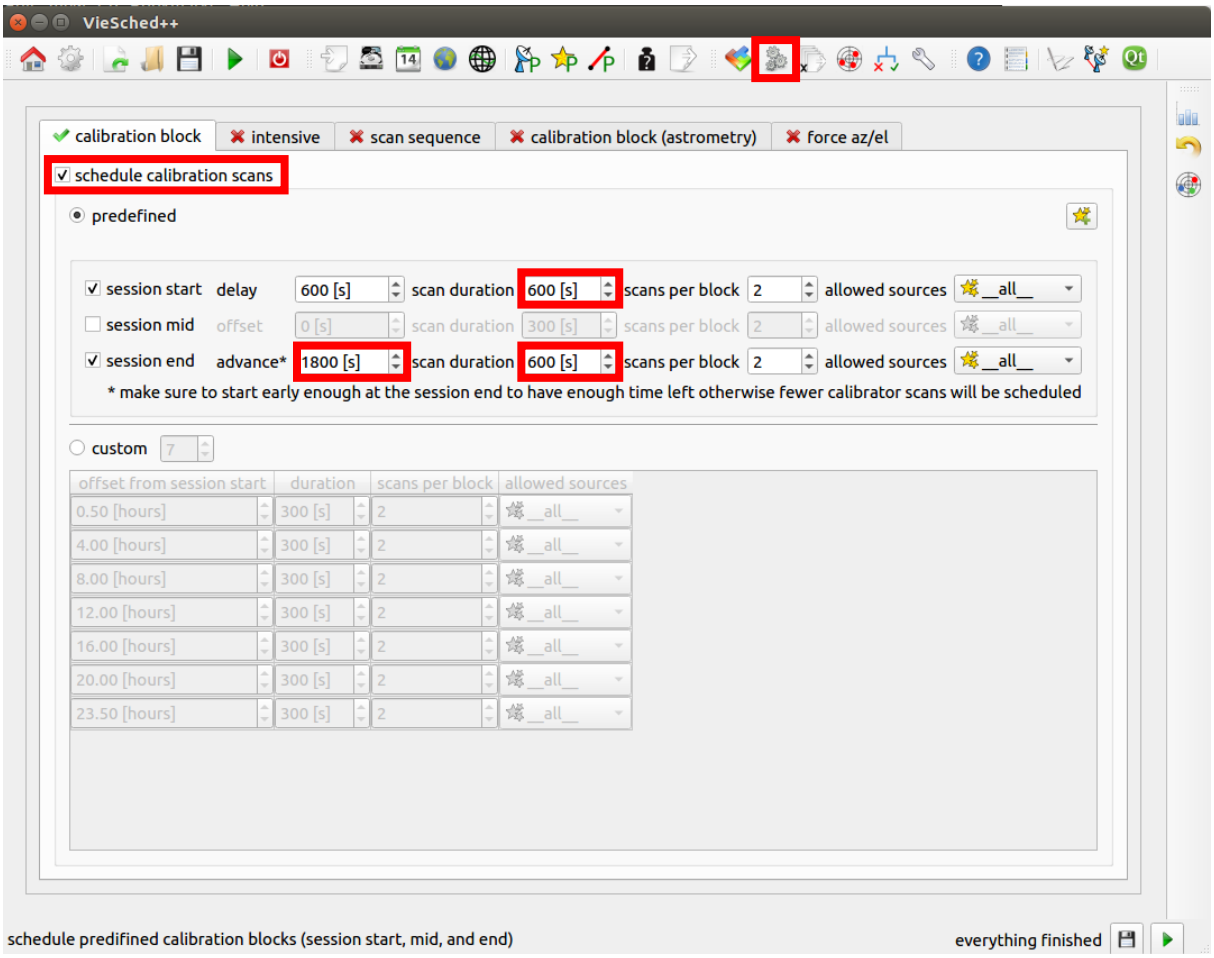
In the following example, I did select the number of observations (blue) together with the dUT1 repeatability (green) and the average 3d station coordinate repeatability (red). Additionally, I did sort the versions based on the best average 3d coordinate values by giving their parameter a weight of -1.00 (I did use a negative value since here low numbers indicate good schedules). Furthermore, I show a relative view of the values and I did remove the minimum value to make changes even more apparent.



Again, in my example, version three is the recommended version since it is on the very left. This means that in reality, I should probably use this version.

Finally, we want to add calibration scans to our schedule to make the correlator happy. Go to the “rules” tab and brose to the “calibration block” page.

Here, you can enable calibrator scans and define some basic rules about how often such a block should be added and how many and how long the scans should be. In general, the default options should work quite well. However, in this session I would recommend to extend the observation time to 600 seconds since we have some low-sensitive stations and a low observation mode. If you want to schedule two 600 second long scans, you should also change the start time of the “session end” block from 1200 seconds to 1800 seconds to give the stations enough time to slew between the sources.



If you now click on run and open an operation notes file, you should see a list of the calibration scans:

```
============================================================
Calibrator scans
Observation listing from file r1966.skd for experiment R1966
Source      Start      DURATIONS
name      yyddd-hhmmss   Ag  Ft  Ht  Ho  Kk  Ma  Nt  Ny  On  Sv  Wz  Ys
1741-038 20272-171000| 657 633 650         629 638 652 636 600 657 638
1749+096 20272-172125| 663 600 619         651 606 600 601 600 625 663
1741-038 20273-163000| 652 600 640         614 625     633 602 652 631
1639-062 20273-164116| 641 641 620         600 610     619 601 638 617
============================================================
```

You will notice, that in this example, there are no calibration scans with Hobart (Ho) and Kokee (Kk). You can try to fix this by changing the weight of the stations or the weight factors but we will not go into this in this example since you should already know how to do this.

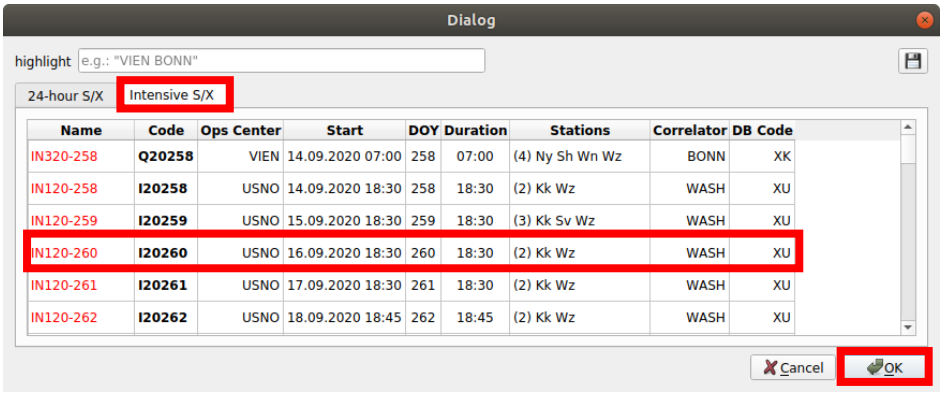
If you are happy with your schedule you could send it to the stations or upload it to the IVS server. At least, you have to distribute the .skd file, the operation notes file and the .vex file. If you browse to the "output" tab in the VieSched++ GUI, it is possible to add some general notes to the generated files as well as provide some contact information. You can make use of this option if you like.

Now, you can restart VieSched++ by clicking on the button and experiment with the next session.

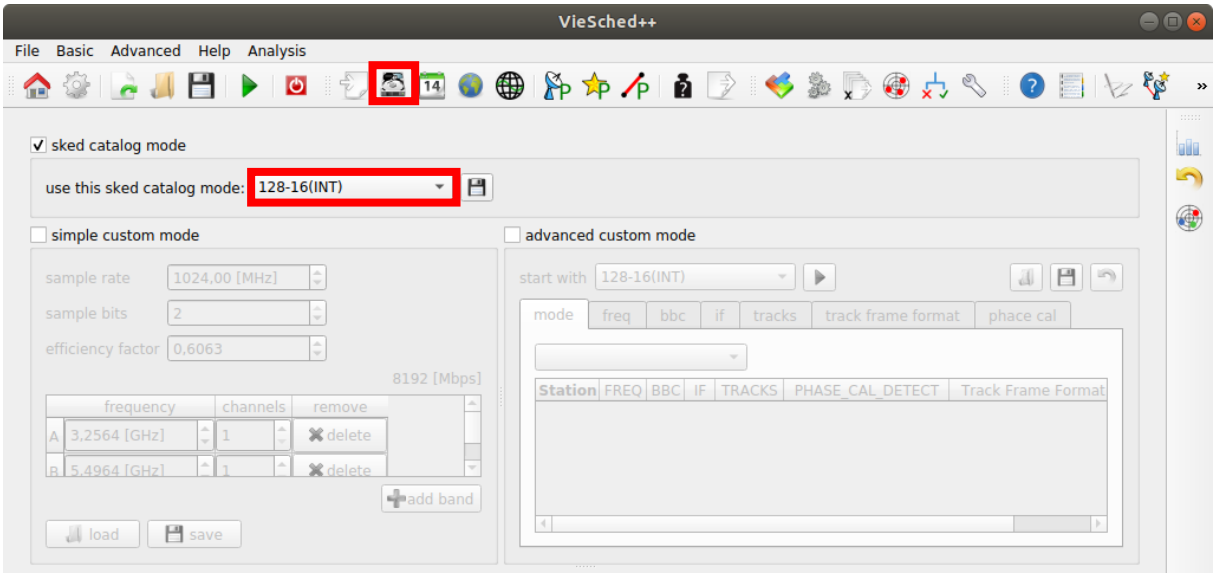
Example 2: standard 1-hour intensive session with two stations

Next we will generate a schedule for an intensive session.

First, make sure that you did restart VieSched++. Now, browse to the "General" tab in the GUI and select session and select session I20260 from the next sessions.



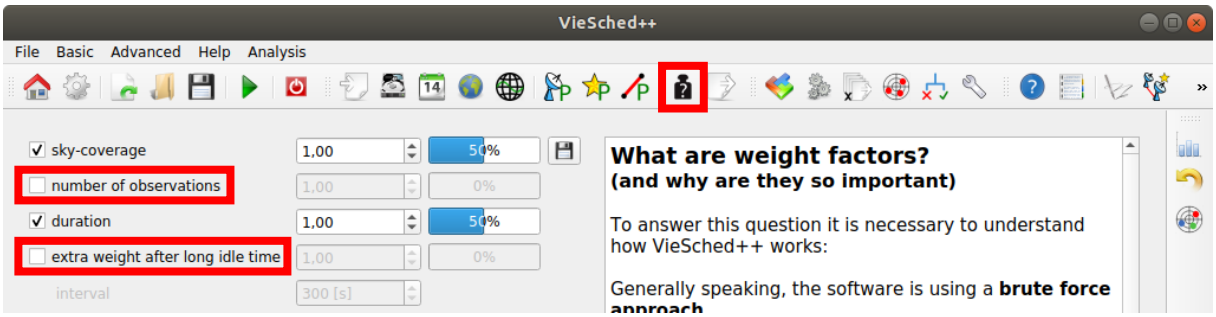
You will see, that this is a one-hour, two-station intensive session between Kokee and Wettzell.
For this session, we need to change the observing mode to "128-16(INT)". Therefore, go to the "Mode" page and select the proper observing mode.



Next, I would recommend to reduce the **maximum allowed observation duration** from 600 seconds to let's say 180 seconds. You can do this using the station setup by changing the default parameter as done before.

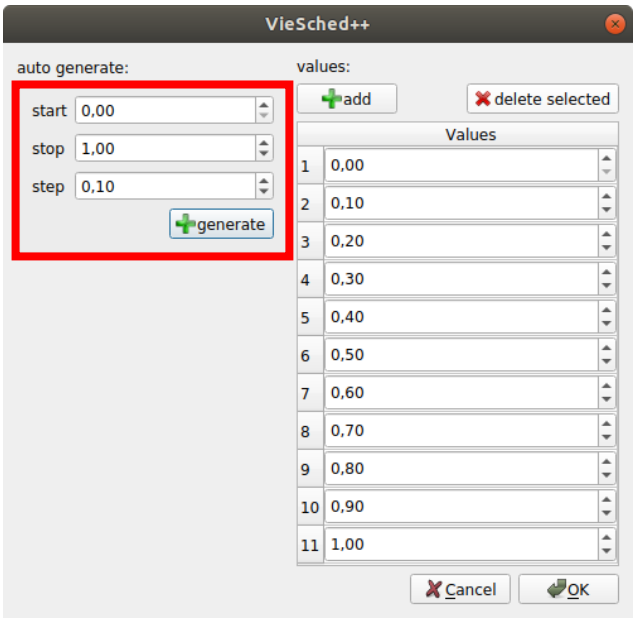
Additionally, we can reduce the **minimum time between two scans to the same source**. This parameter can be found in the source setup. You can, again, change the default parameter. Have a look for the "fixed minimum time between scans" parameter and change it from the default 1800 seconds to 1200 seconds.

In case of intensive session, the complexity of the optimization problem you have to solve is far less compared to the complexity of a global 24-hour session. In particular, we want **all stations to always observe together**. Therefore, the "number of observations" weight factor and the "extra weight after long idle time" weight factor are irrelevant. (Remember that the "number of observations" optimization criterion is based on the number of observations per scan, not per session. Additionally, there will never be long idle times since all stations are always observing together.) Let's browse to the weight factor page and disable the two unnecessary weight factors.

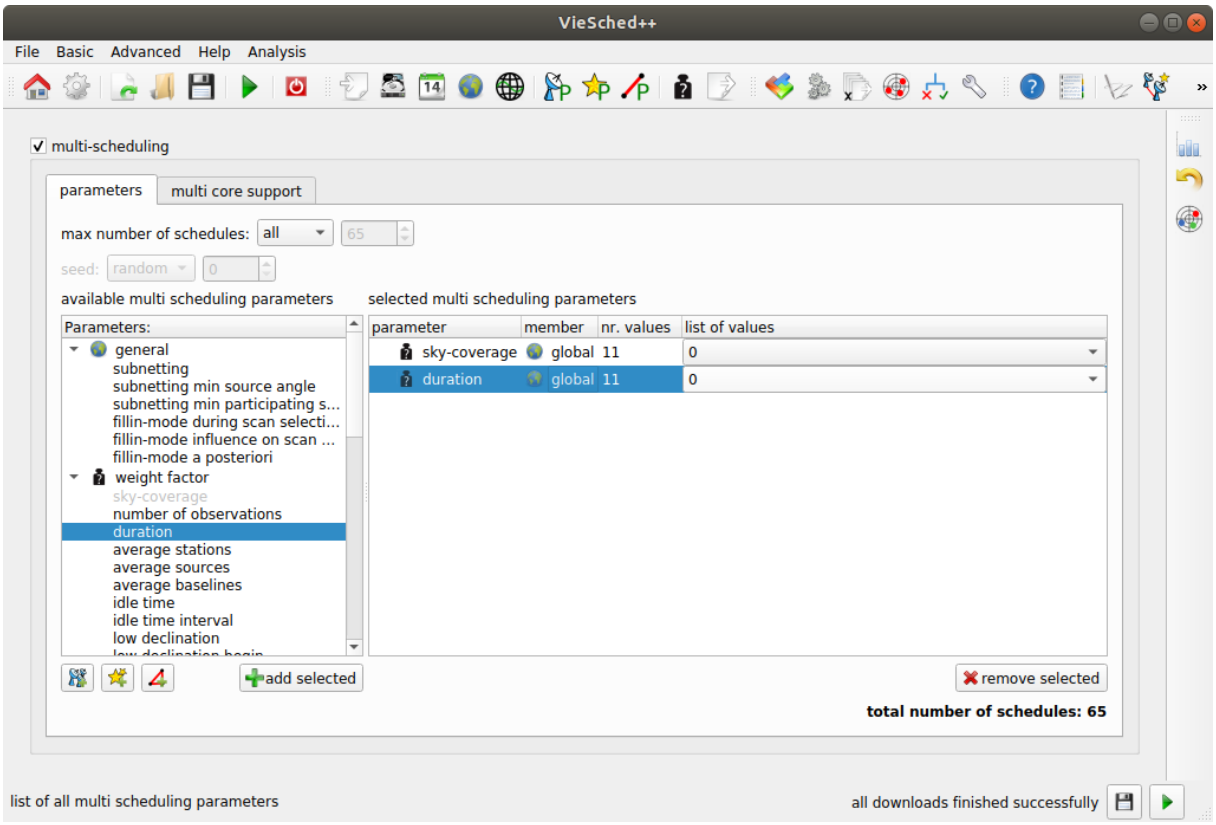


For the two remaining weight factors, we want to use the multi-scheduling tool again to test different combination of values.

Browse to the multi-scheduling page, select one of the weight factors on the left and click on "add selected". Since intensives are processed very fast, you can test a lot more different values now. You can use the "start", "stop" and "step" option to auto-generate values by clicking on "generate".

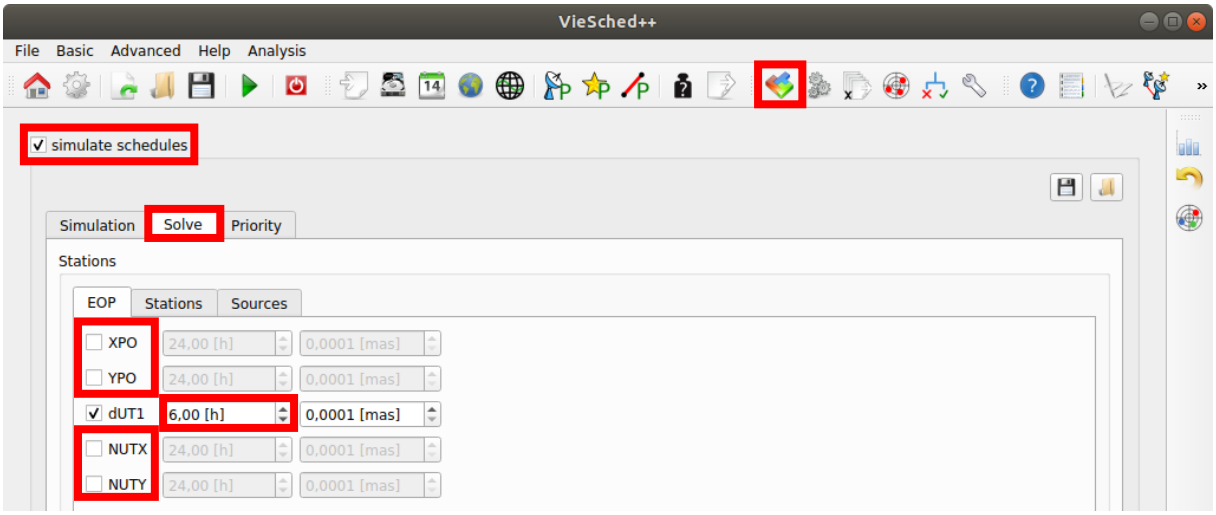


Finally, your multi-scheduling setup should look something like this and a total of 65 schedules should be generated

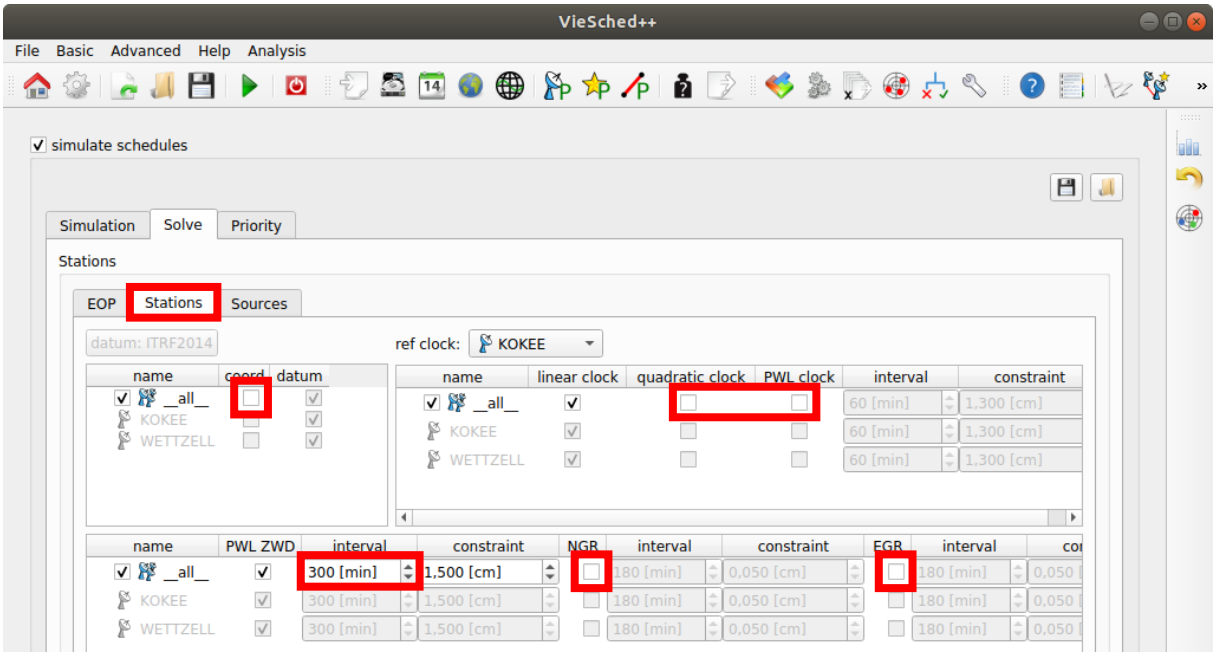


For intensives, it is necessary to significantly **change the simulation or in particular the parameter estimation**. Since you typically have only few stations and only few observations, it is not possible to estimate everything as it is done during a global 24-hour session. However, the default settings are especially chosen for global 24-hour session.

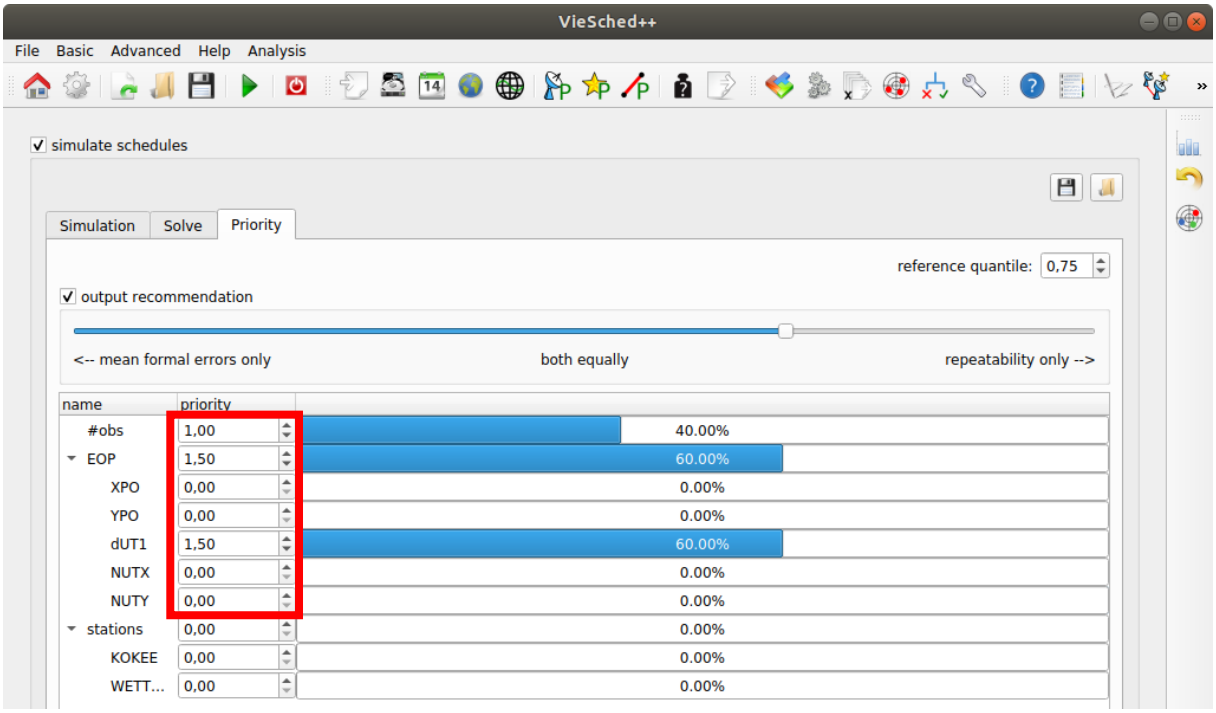
Go to the "Simulation" page and browse to the "Solve" tab. From the earth orientation parameters, you should only estimate dUT1. I would also recommend to estimate the dUT1 parameter not every 24 hours but fewer, e.g.: every six hours. The exact interval is not important since we put very tight constraints on the estimates (0.0001 milliarcseconds) and thus are estimating one offset only.



Next, we need to adjust the estimated parameters related to stations.
In typical intensives, we are not going to estimate station coordinates. Additionally, we only want to estimate a linear clock and a linear zenith wet delay (ZWD).
Therefore, browse to the “Stations” tab and deselect station coordinates, the quadratic and piecewise linear part of the clock and the north gradient (NGR) and east gradient (EGR). You should also increase the interval of the ZWD to make sure that you do only estimate one linear term for the full session. To be on the save side, I did change the interval to 300 minutes here.



Finally, I can adjust the priorities of the session to get a recommendation about the best schedule by VieSched++. For the intensive session, we are only interested in dUT1 accuracies:



As noted before, I would always recommend to add a high number of observations (#obs) as an additional prime goal of the session.

Finally, we can start the scheduling and have a look at the output.

First, check that there were not errors in the log file and have a look which version VieSched++ would recommend.

Next, you can have a look at one simulation log files e.g.: **i20260_v001_simulator.txt**. Here you can have a look at the list of estimated parameters to check that everything is the way you want it to be:

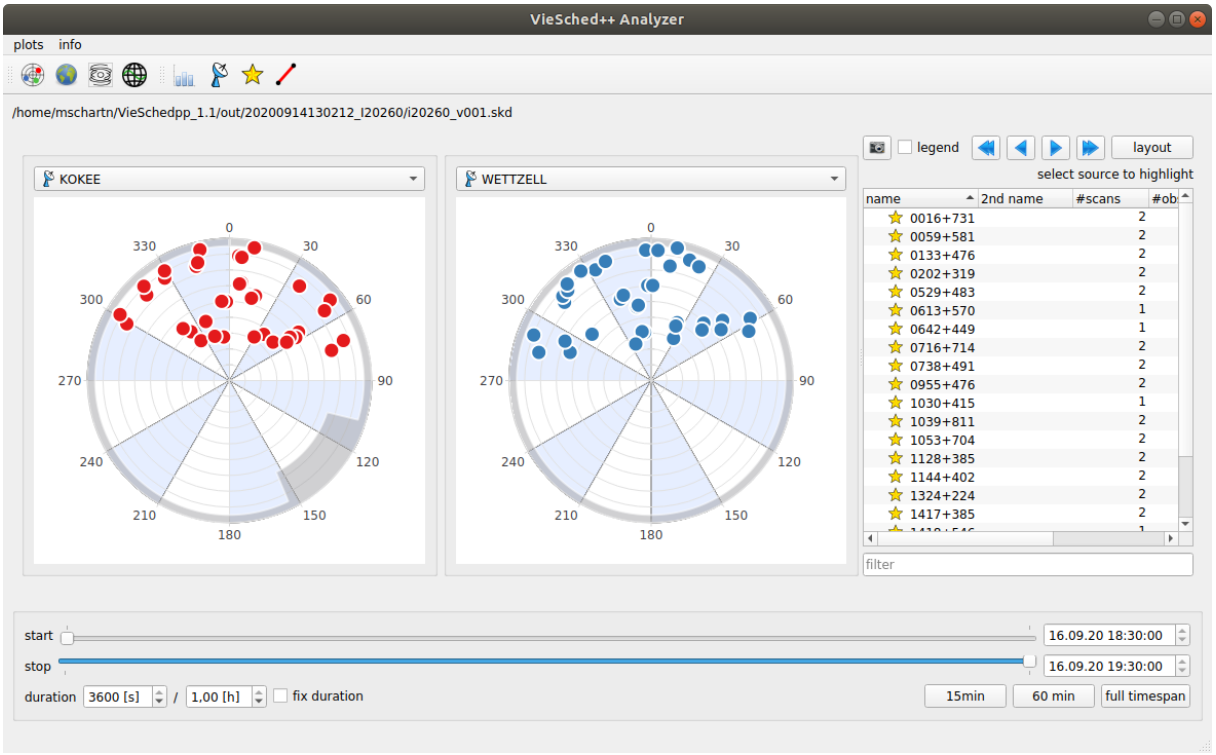
List of estimated parameters

#	Type	member	reference epoch	sigma [unit]	repeatability [unit]
0	lin_CLK	WETTZELL	--	0.00005 [cm/day]	0.00008 [cm/day]
1	PWL_ZWD	KOKEE	2020.09.16 15:00:00	1.35839 [cm]	3.38939 [cm]
2	PWL_ZWD	KOKEE	2020.09.16 20:00:00	0.34604 [cm]	1.60935 [cm]
3	PWL_ZWD	WETTZELL	2020.09.16 15:00:00	1.43750 [cm]	3.87403 [cm]
4	PWL_ZWD	WETTZELL	2020.09.16 20:00:00	0.30378 [cm]	1.60793 [cm]
5	PWL_dUT1	--	2020.09.16 18:00:00	0.14118 [mas]	0.20362 [mas]
6	PWL_dUT1	--	2020.09.17 00:00:00	0.14118 [mas]	0.20362 [mas]

You can see, that we are now only estimating 7 parameters:

- one linear clock for Wettzell
- two piecewise estimates of the ZWD per station resulting in one linear trend of the ZWD per station
- two piecewise linear estimates for dUT1 that are very tightly constraint resulting in one offset for dUT1

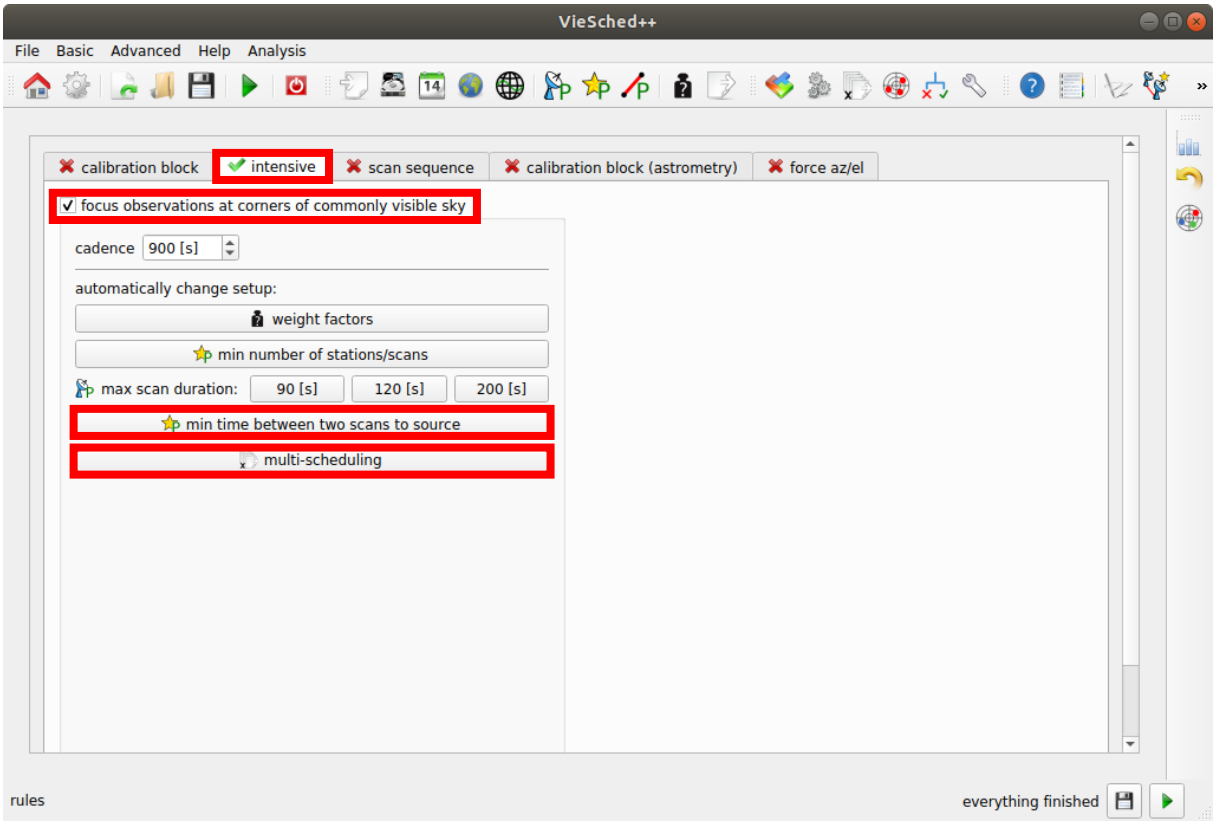
You can again use the **VieSched++ Analyzer** to explore the recommended schedule. Go to the “Analyzer” tab and brows for the .skd file you have just generated. Now you can click on the “run session analyzer” button. Take some time to investigate the sky-coverage and use the sliders on the bottom to limit the display to a shorter duration.



As you can see, the observations are well distributed in the north and there are no observations pointing into the south. This can be easily explained by the network and the location of the two antennas.

VieSched++ provides a special algorithm that could be used for scheduling intensive sessions. The idea is, that in theory, observations at the corners of the commonly visible sky have a lot higher influence on the accuracy of dUT1 than other observations. However, due to the remote location of these observations and the required slewing, these observations are often times avoided by the scan selection algorithm.
This is where the special **intensive algorithm** comes in play. This algorithm forces VieSched++ to observe sources that lie in the corners of the commonly visible sky. This is done every couple of minutes (by default every 15 minutes) and it will alternate between the two corners.

You can enable this option on the "Rules" page, by browsing to the "intensive" page.



Here, you can also find shortcuts to other parameters changes that typically have to be done for intensive scheduling, e.g.: the " weight factors" button will make sure that only the two relevant weight factors are selected (as we have done manually). It is also possible to set a maximum scan duration of 90, 120, or 200 seconds (as we have done manually), or to enable some reasonable multi-scheduling.

You should click on the " min time between two scans to source" and " multi-scheduling" button but you can ignore the rest since we manually adjusted the parameters already.

Finally, you can restart the scheduling again.

You should take some time and go to the "Analyzer" tab again, load the new best schedule and have a look at the sequence of observations. As you can note, the new schedule should start with observing one source at the very corner of the observations.

If you have a look at the iteration log file, e.g. **i20260_v001_iteration_0.txt**, you can see when and how the software tries to force a scan to a source at the corner of the commonly visible sky.

```
.-------------------------------------------------------------------------------------------------------------------------------------------------------.
|                                                reweight sources to focus observation at corner                                                        |
| readjust source selection at corner (fraction 1.556)                                                                                                  |
| readjust source selection at corner (fraction 1.372)                                                                                                  |
| readjust source selection at corner (fraction 1.646)                                                                                                  |
| readjust source selection at corner (fraction 1.411)                                                                                                  |
|     increase weight of source 1324+224 to 1000.00                                                                                                     |
|     increase weight of source 0202+319 to  909.41                                                                                                     |
|     increase weight of source 1145+268 to  728.08                                                                                                     |
|     increase weight of source 1308+328 to  722.93                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| depth:  0                                                                                                    considered single scans 33 |
| scan:   no0000   (id: 42)                                                                                  duration: 18:30:00 - 18:31:06 |
| Source: 1324+224 (id: 181)                                                                               type: target single source scan |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|
|     station  | delay |  slew |  idle | preob |  obs  |       duration      |        az [deg]     |       unaz [deg]      |       el [deg]     |
|              |  [s]  |  [s]  |  [s]  |  [s]  |  [s]  |    start - end      |    start - end      |     start - end       |   start - end      |
|--------------|-------|-------|-------|-------|-------|---------------------|---------------------|-----------------------|--------------------|
|     KOKEE    |     0 |     0 |     0 |     0 |    66 | 18:30:00 - 18:31:06 |  70.0590 -  70.1475 |  430.0590 -  430.1475 |  9.8788 - 10.1190 |
|     WETTZELL |     0 |     0 |     0 |     0 |    66 | 18:30:00 - 18:31:06 | 280.9958 - 281.1918 |  640.9958 -  641.1918 | 19.9941 - 19.8171 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|
```

Now it is your time to try to improve the session even further.
For example: we did use corner switch cadence of 900 seconds. Maybe 600 seconds would be better? Maybe it is better to only allow 120 second long scans? Maybe there is anything else that should be changed. You should now be able to investigate this by yourself and generate schedules and simulations on your own.