9th VieVS User Workshop, Vienna, September 11 – 12, 2018

VIE_LSM 3.1

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TU WIEN VieVS
Vienna VLBI and Satellite Software

TU WIEN GEO

Outline

1. Introduction
2. Estimated parameters in vie_lsm
3. Piece-wise linear offset (PWLO) functions
4. Partial derivatives of the PWLO functions
5. Least-Squares adjustment in vie_lsm
6. Correcting large clock errors and clock breaks in a first least-squares solution
7. Main parameterisation of least-squares adjustment in VieVS
8. Conclusions

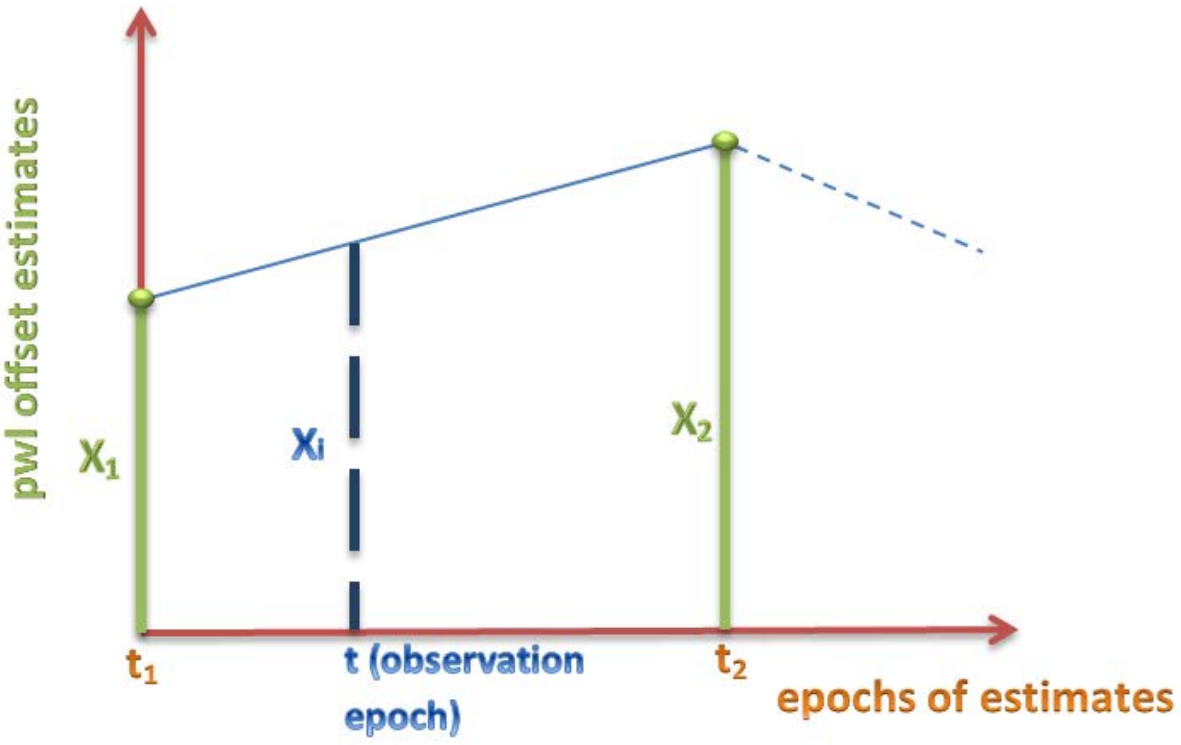
1. Introduction

- “vie_lsm” is a module of “VieVS”, which estimates geodetic parameters with Gauss Markov least squares adjustment from VLBI observations.
- All the parameters can be estimated as piece-wise linear offsets (PWLO) in sub-daily and daily temporal resolution.
- Station- and source-wise parameterisation allows to change station- and source-specific parameters for each station and source independently.

2. Estimated parameters in vie_lsm

- Clock errors: offset (cm) + rate (cm/day) + quadratic term (cm/day^2) + PWLO (cm),
- Zenith wet delays (cm) as PWLO,
- Troposphere gradients (cm) as PWLO,
- EOP (mas and ms) as PWLO,
- Antenna coordinates in TRF (cm) as one offset per session or as PWLO,
- Source coordinates in CRF (declinations in mas and right ascensions in ms) as one offset per session or as PWLO.

3. Piece-wise linear offset (PWLO) functions



$$x_i = x_1 + \frac{t - t_1}{t_2 - t_1}(x_2 - x_1)$$

4. Partial derivatives of the PWLO functions

$$\frac{\partial \tau(t)}{\partial x_1} = \frac{\partial \tau(t)}{\partial x_i} \cdot \frac{\partial x_i}{\partial x_1} \longrightarrow \frac{\partial x_i}{\partial x_1} = 1 - \frac{t - t_j}{t_{j+1} - t_j}$$

$$\frac{\partial \tau(t)}{\partial x_2} = \frac{\partial \tau(t)}{\partial x_i} \cdot \frac{\partial x_i}{\partial x_2} \longrightarrow \frac{\partial x_i}{\partial x_2} = \frac{t - t_j}{t_{j+1} - t_j}$$

$$t_j < t < t_{j+1}$$

5. Least-squares adjustment in vie_lsm

$$A = \begin{bmatrix} A(1).sm & \cdots & A(15).sm \end{bmatrix}$$ → design matrix of real observation equations

$$H = \begin{bmatrix} H(1).sm & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & H(15).sm \end{bmatrix}$$ → design matrix of pseudo-observation equations (constraints)

$$N = \begin{bmatrix} A^T PA + H^T P_H H & C^T \\ C & 0 \end{bmatrix} \quad b = \begin{bmatrix} A^T Poc + H^T P_H och \\ b_c \end{bmatrix}$$

b_c is a zero vector (due to NNT and NNR conditions

$$x = N^{-} b$$ → parameter vector (estimates)

$$m_0 = (v^T Pv + v_H^T P_H v_H) / (n_{obs} + n_{constr} - n_{unk})$$

$$K_x = m_0 N^{-}$$ → variance-covariance matrix of the estimates

6. Correcting large clock errors and clock breaks in a first least-squares solution

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File Models Estimation Global solution Scheduling Simulation Run Plotting Help

VieVS estimation settings

First solution

- [x] Run first solution (only following clock function)
  - ( ) one offset per clock
  - ( ) one offset & one rate per clock
  - (•) one offset, one rate & one quadratic term per clock

Main solution

- [x] Run main solution (parameter estimation)
  - [ ] Simple outlier test (c * m0)
  - [ ] Normal outlier test (c * m0 * sqrt(qvv))

c: 5

- [ ] Apply baseline dependent weights (only vie_lsm)
- [x] Estimate parameters (otherwise: only N matrix created)

Write all parameters to ASCII file [Save as...]

- [ ] Allow for stationwise and sourcewise parameterization for each session

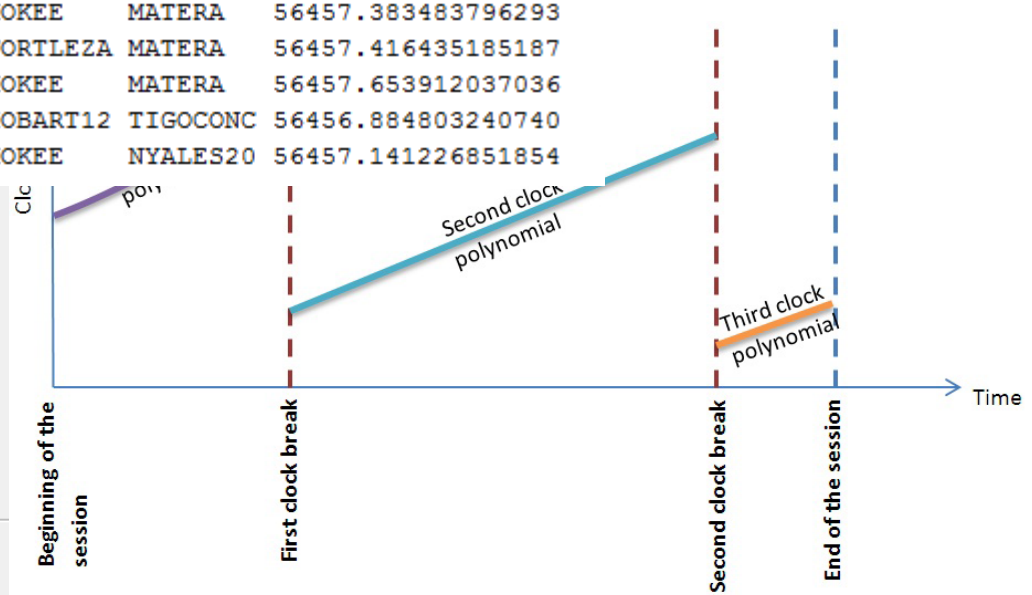
Add constant noise to observations [cm]: 1

- [ ] Introduce elevation dependent noise (only vie_lsm)

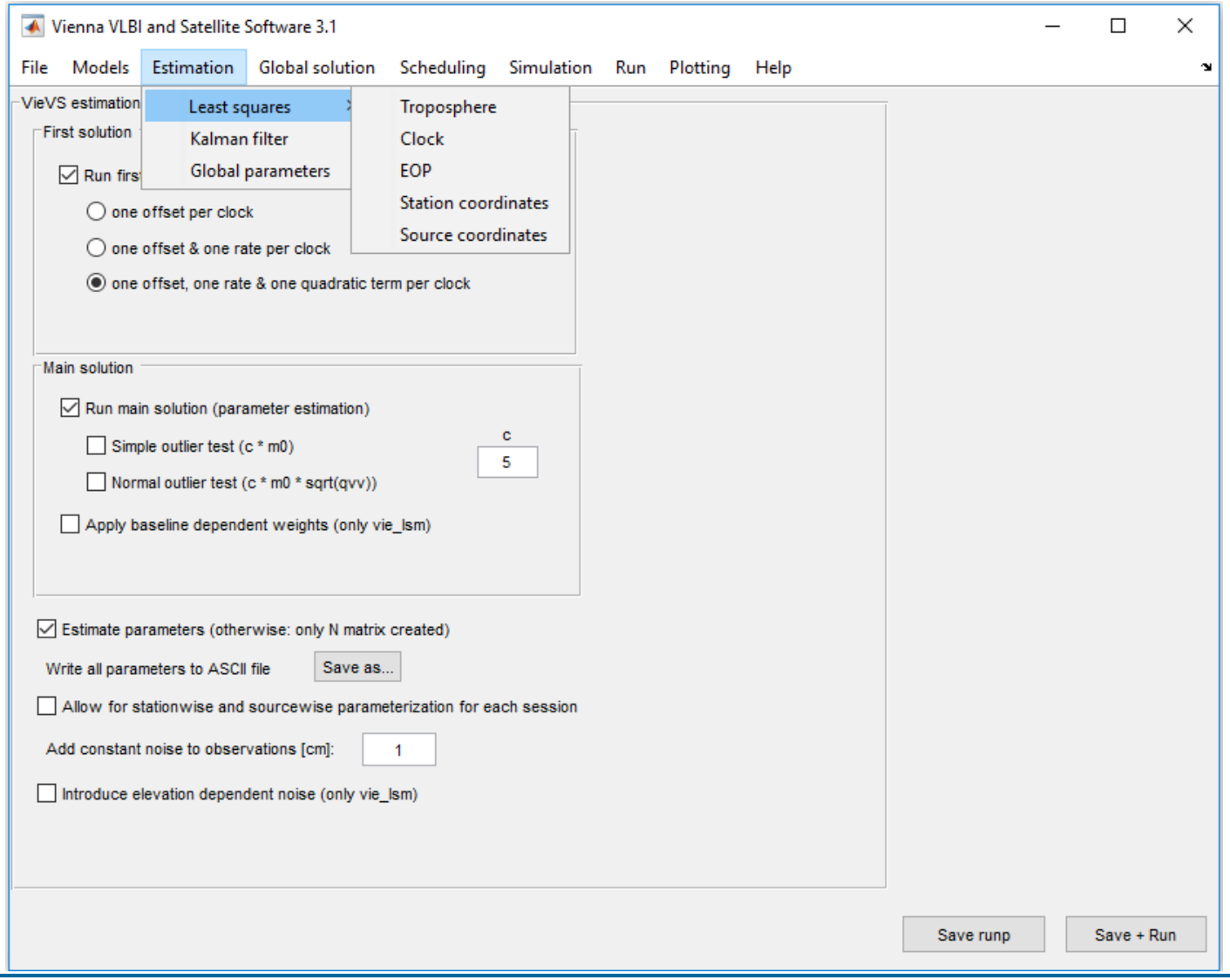
A first LS solution is done for reducing large clock errors from the observations and for fixing clock breaks.

New outlier observations are detected and written to text files VieVS/VLBI/DATA/OUTLIER/YOURDIR/YEAR/SESSNAME.OUT

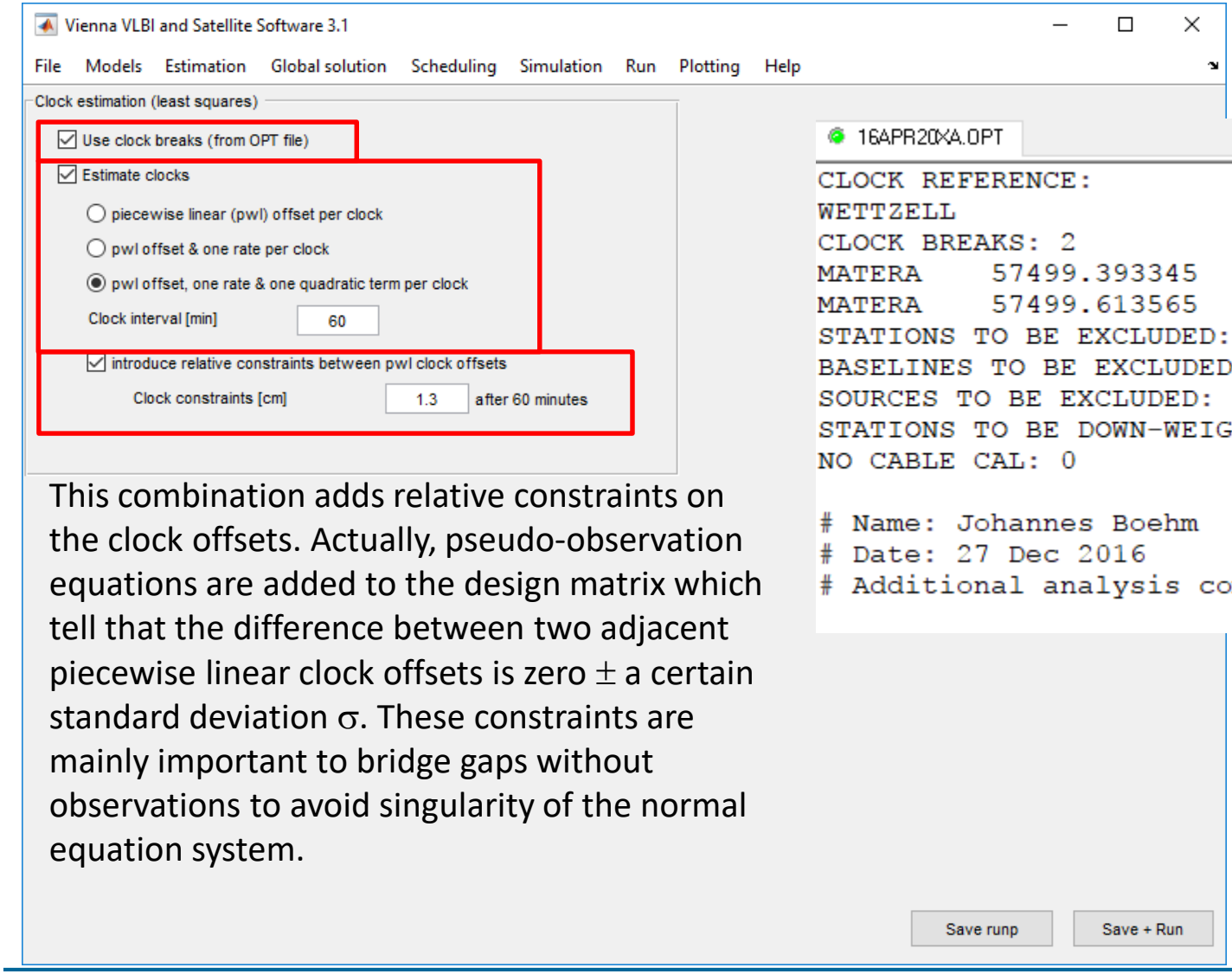
```
KOKEE     MATERA    56457.213020833333
KOKEE     WETTZELL  56457.141226851854
KOKEE     MATERA    56457.383483796293
FORTLEZA  MATERA    56457.416435185187
KOKEE     MATERA    56457.653912037036
HOBART12  TIGOCONC  56456.884803240740
KOKEE     NYALES20  56457.141226851854
```



7. Main parameterisation of least-squares adjustment in VieVS



7.1. Synchronisation errors between clocks



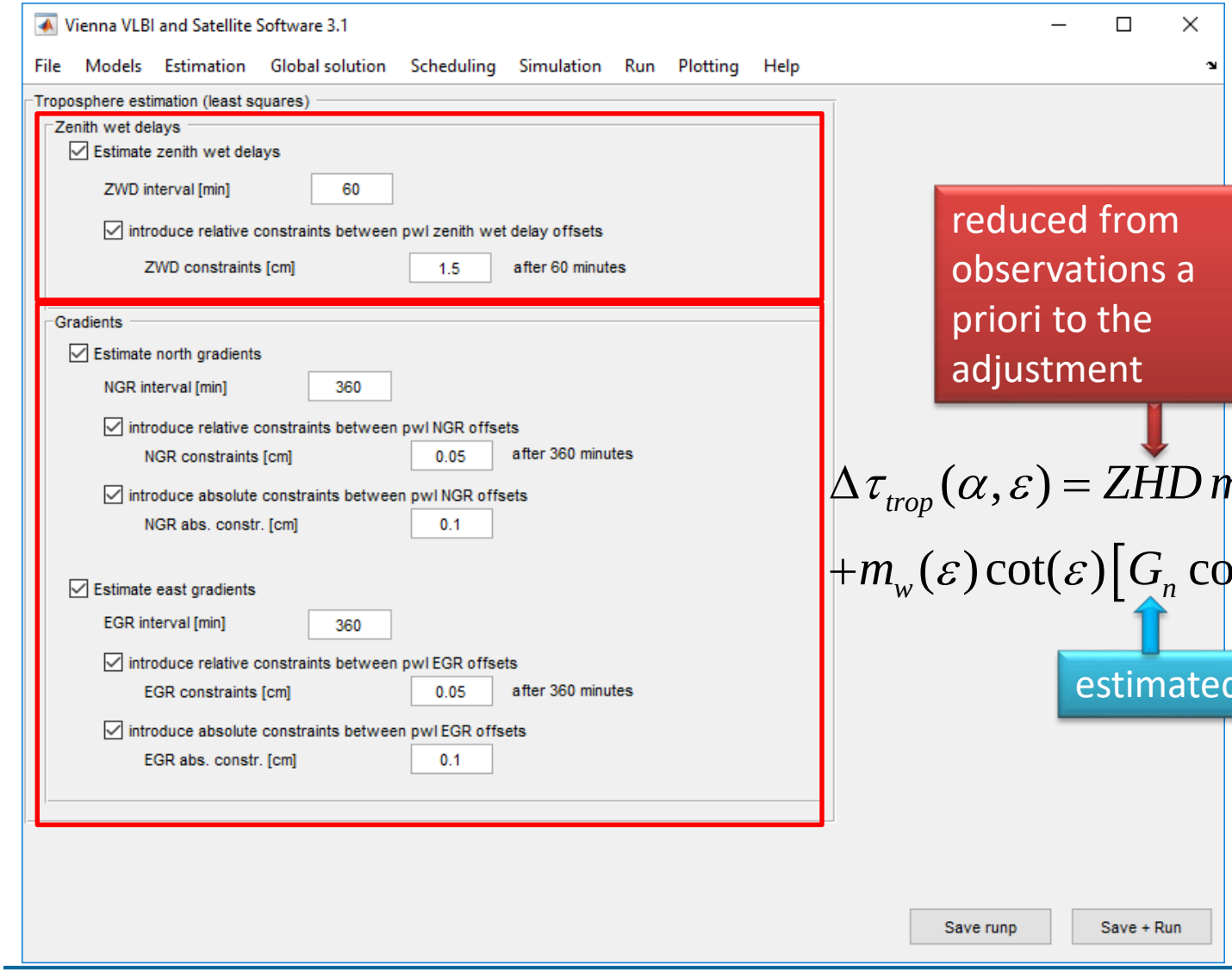
16APR20XA.OPT

```
CLOCK REFERENCE:
WETTZELL
CLOCK BREAKS: 2
MATERA     57499.393345
MATERA     57499.613565
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

# Name: Johannes Boehm
# Date: 27 Dec 2016
# Additional analysis comments (optional):
```

This combination adds relative constraints on the clock offsets. Actually, pseudo-observation equations are added to the design matrix which tell that the difference between two adjacent piecewise linear clock offsets is zero $\pm$ a certain standard deviation σ. These constraints are mainly important to bridge gaps without observations to avoid singularity of the normal equation system.

7.2. Troposphere delays (ZWD and gradients)



reduced from observations a priori to the adjustment

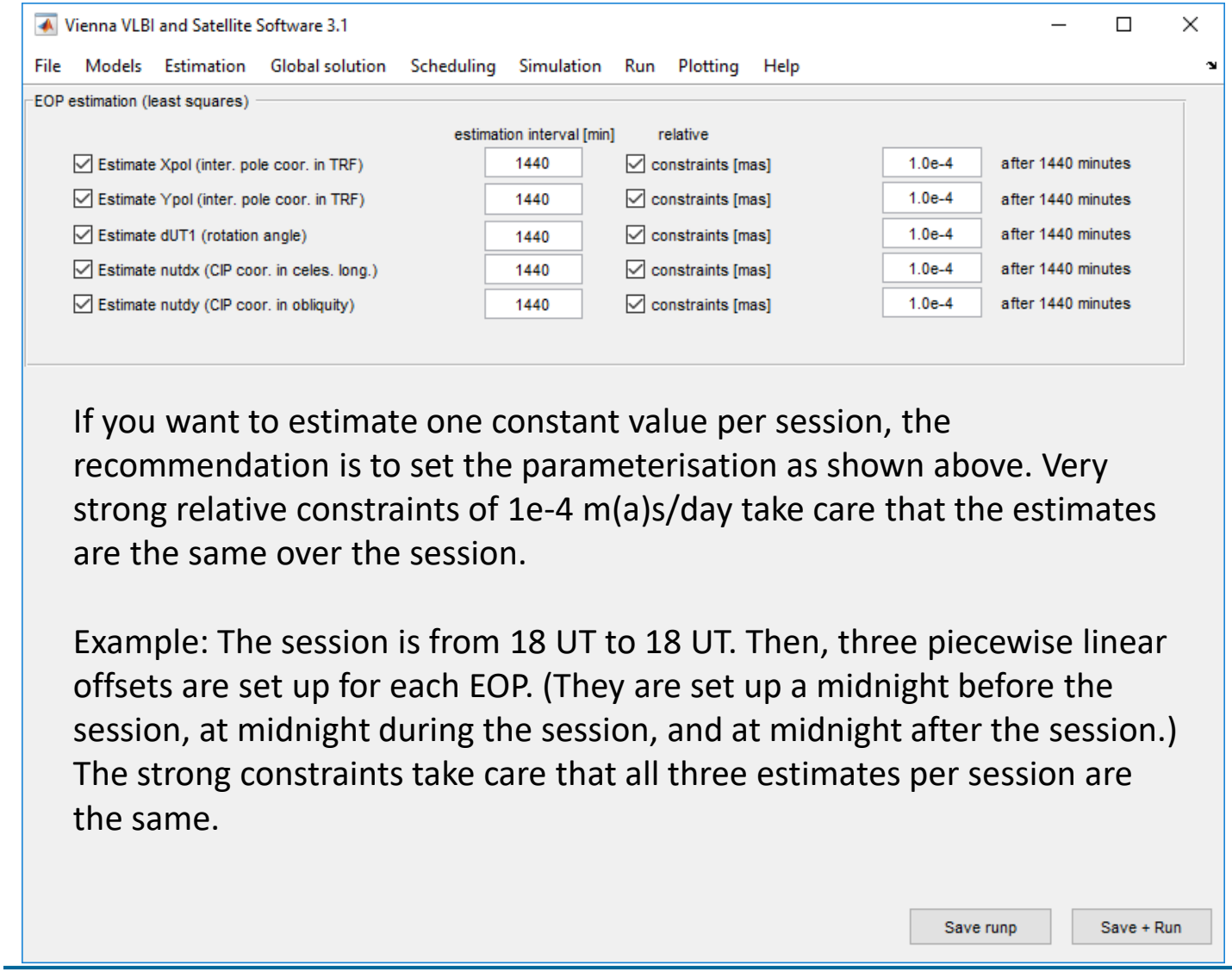
estimated

$$\Delta\tau_{trop}(\alpha,\varepsilon) = ZHD\, m_h(\varepsilon) + ZWD\, m_w(\varepsilon)$$
$$+ m_w(\varepsilon)\cot(\varepsilon)\left[G_n\cos(\alpha) + G_e\sin(\alpha)\right]$$

estimated

estimated

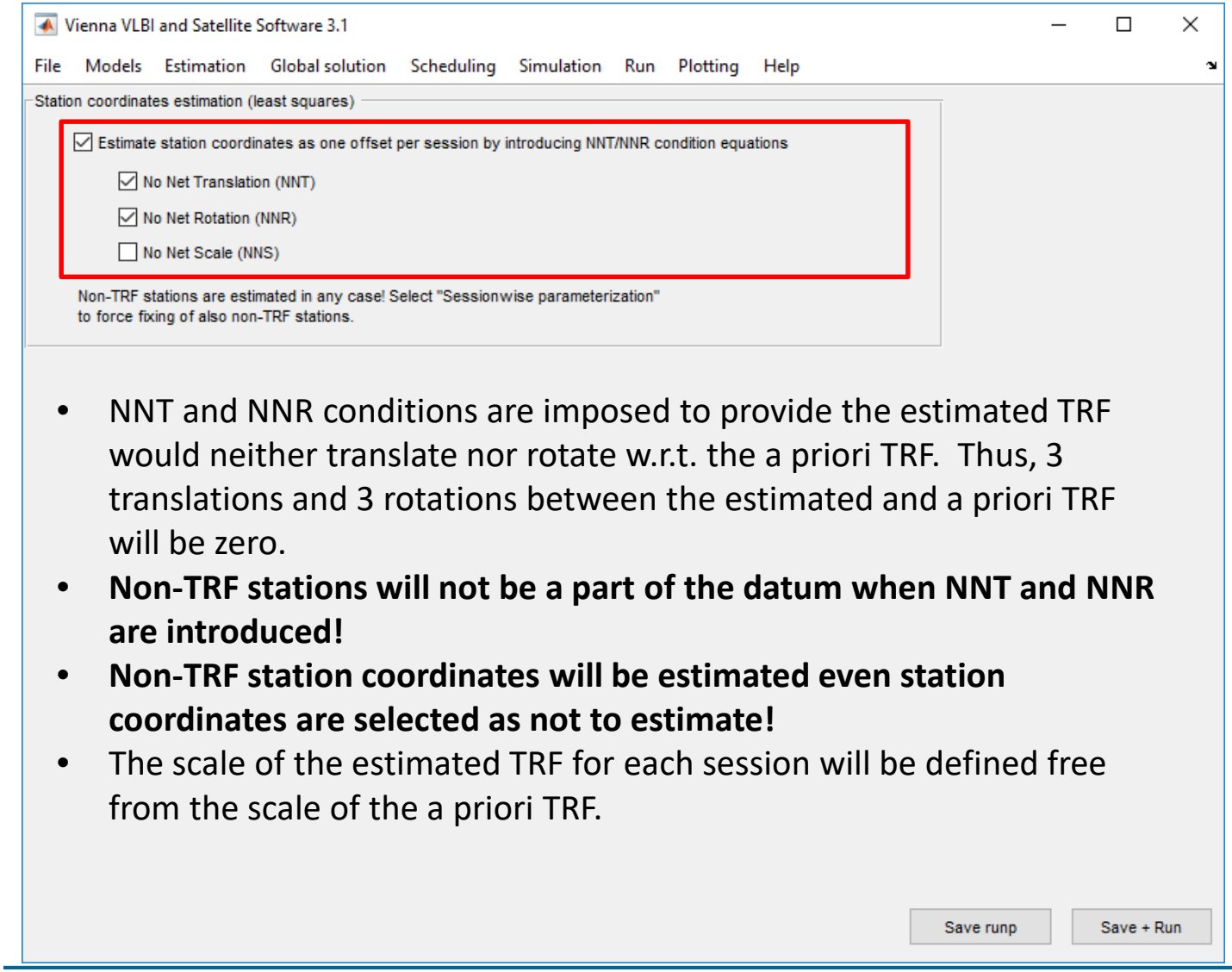
7.3. Earth Orientation Parameters



If you want to estimate one constant value per session, the recommendation is to set the parameterisation as shown above. Very strong relative constraints of 1e-4 m(a)s/day take care that the estimates are the same over the session.

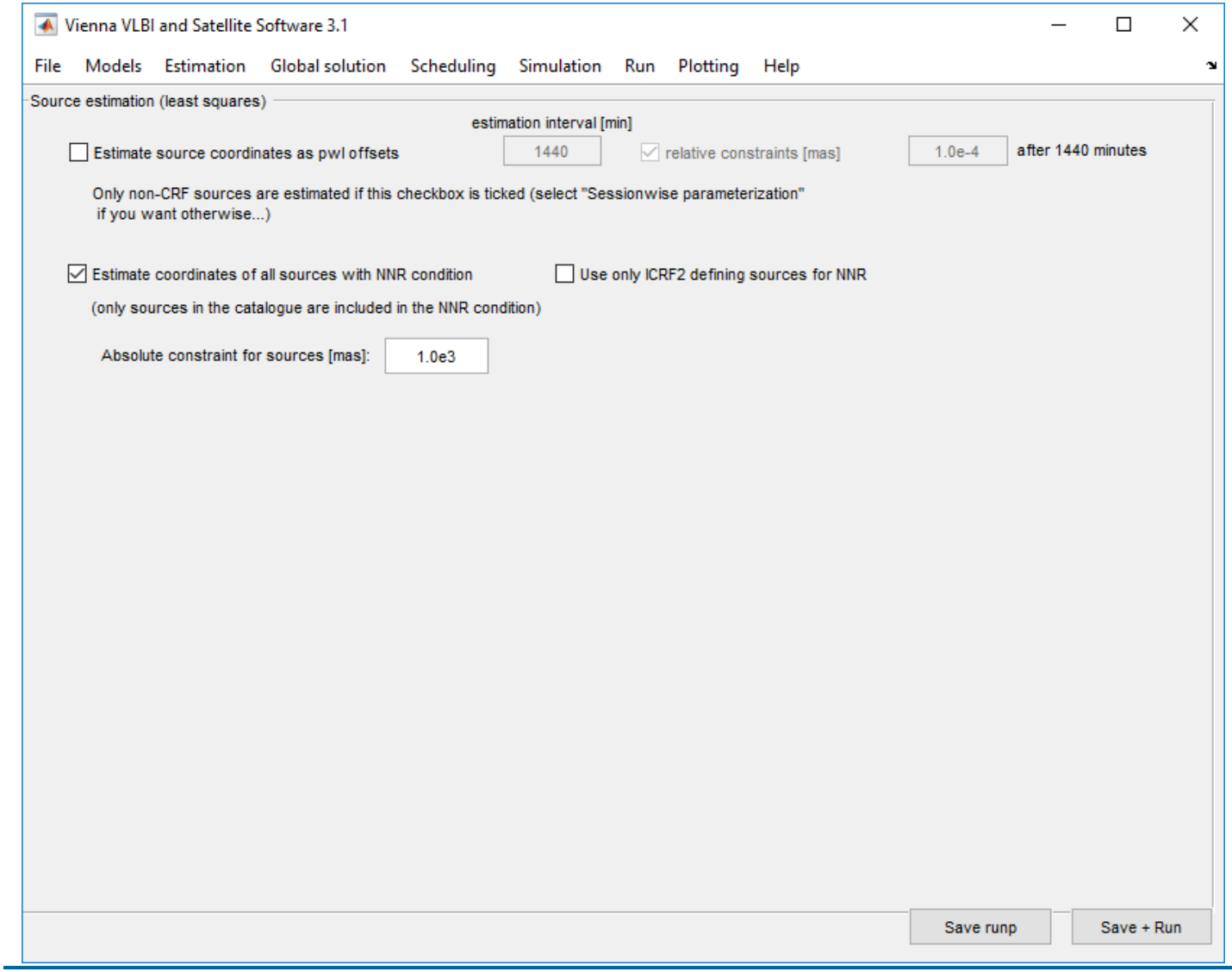
Example: The session is from 18 UT to 18 UT. Then, three piecewise linear offsets are set up for each EOP. (They are set up a midnight before the session, at midnight during the session, and at midnight after the session.) The strong constraints take care that all three estimates per session are the same.

7.4. Antenna TRF coordinates

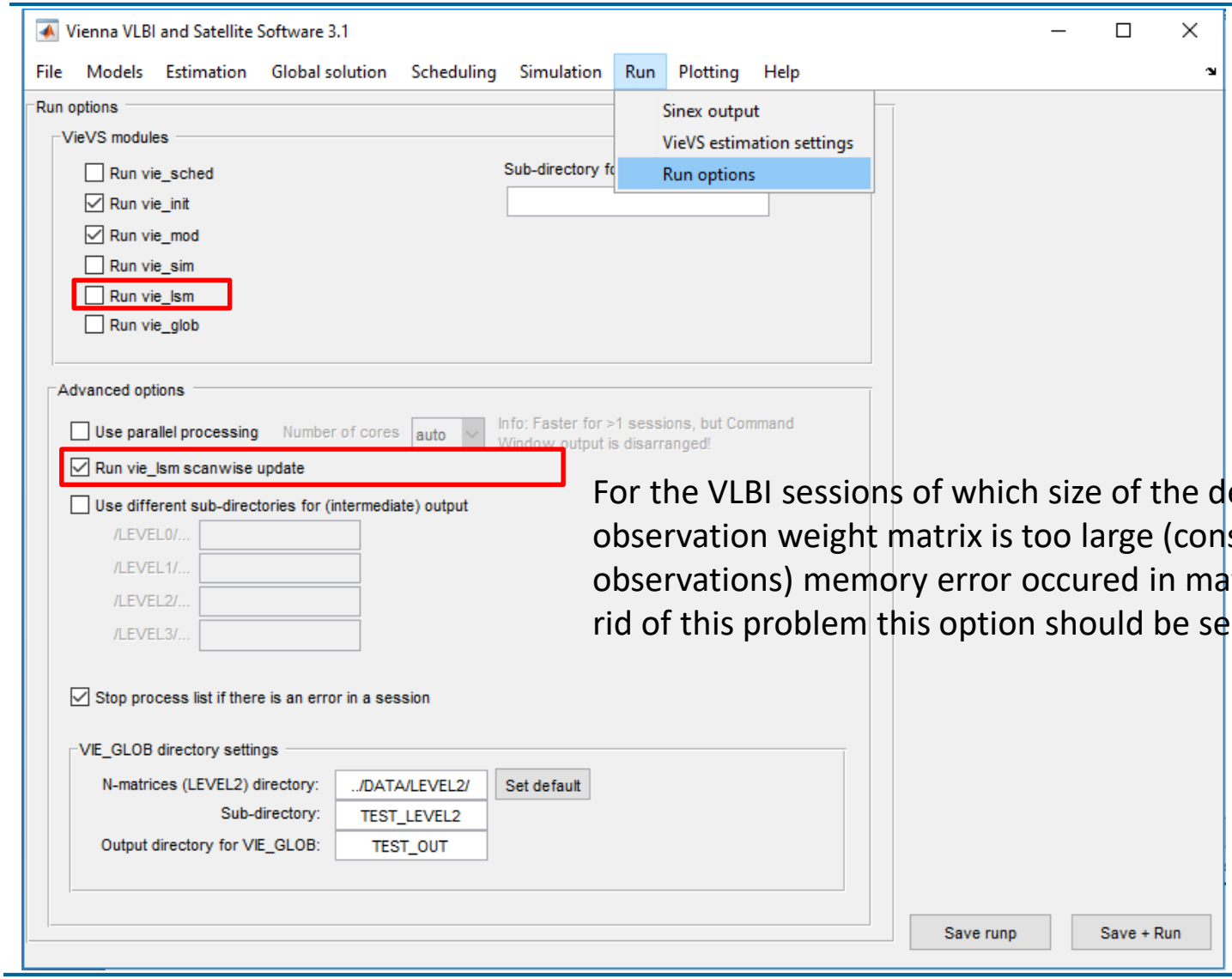


- NNT and NNR conditions are imposed to provide the estimated TRF would neither translate nor rotate w.r.t. the a priori TRF. Thus, 3 translations and 3 rotations between the estimated and a priori TRF will be zero.
- **Non-TRF stations will not be a part of the datum when NNT and NNR are introduced!**
- **Non-TRF station coordinates will be estimated even station coordinates are selected as not to estimate!**
- The scale of the estimated TRF for each session will be defined free from the scale of the a priori TRF.

7.5. Source CRF coordinates

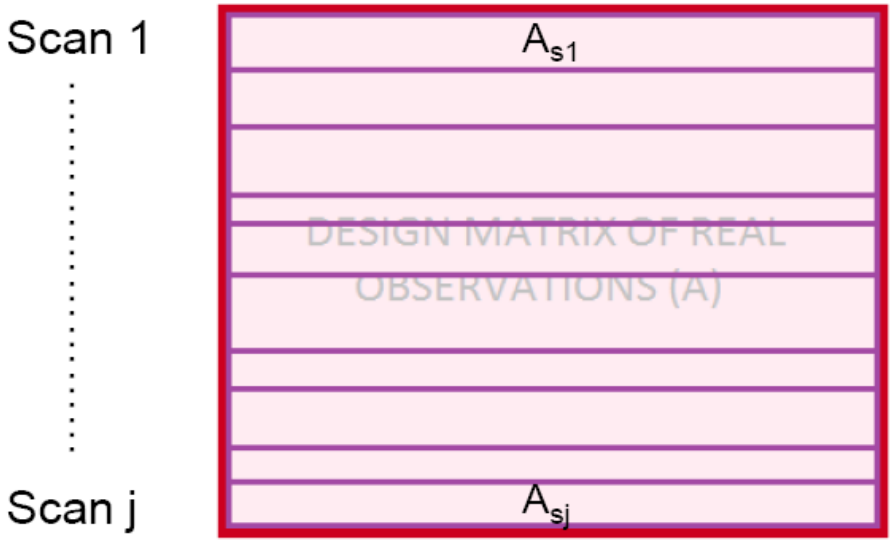


7.6. vie_lsm scan-wise update



For the VLBI sessions of which size of the design matrix and observation weight matrix is too large (consists too many observations) memory error occured in matlab. In order to get rid of this problem this option should be selected!

7.7. Scan-wise update of normal equations



$$N_{s1} = A_{s1}^T \cdot P_{s1} \cdot A_{s1}$$

$$N_A = N_{s1} + N_{s2} + \ldots + N_{sj}$$

$$b_{s1} = A_{s1}^T \cdot P_{s1} \cdot oc_{s1}$$

$$b_A = b_{s1} + b_{s2} + \ldots + b_{sj}$$

j : number of scans in the session

Claudia Tierno Ros, Third VieVS user workshop, 11-13 September, 2012

8. Conclusions

- vie_lsm corrects clock breaks and detects outlier observations.
- vie_lsm provides SINEX input and datum free normal equations for global solutions.
- PWLO estimates of VieVS are in a good agreement with those derived from other space geodetic techniques.
- Scan-wise update of normal equation system ensures a successful process of the future sessions with lots of observations.
- Station-wise and source-wise parameterisation allows to investigate on several site- and source-specific features.

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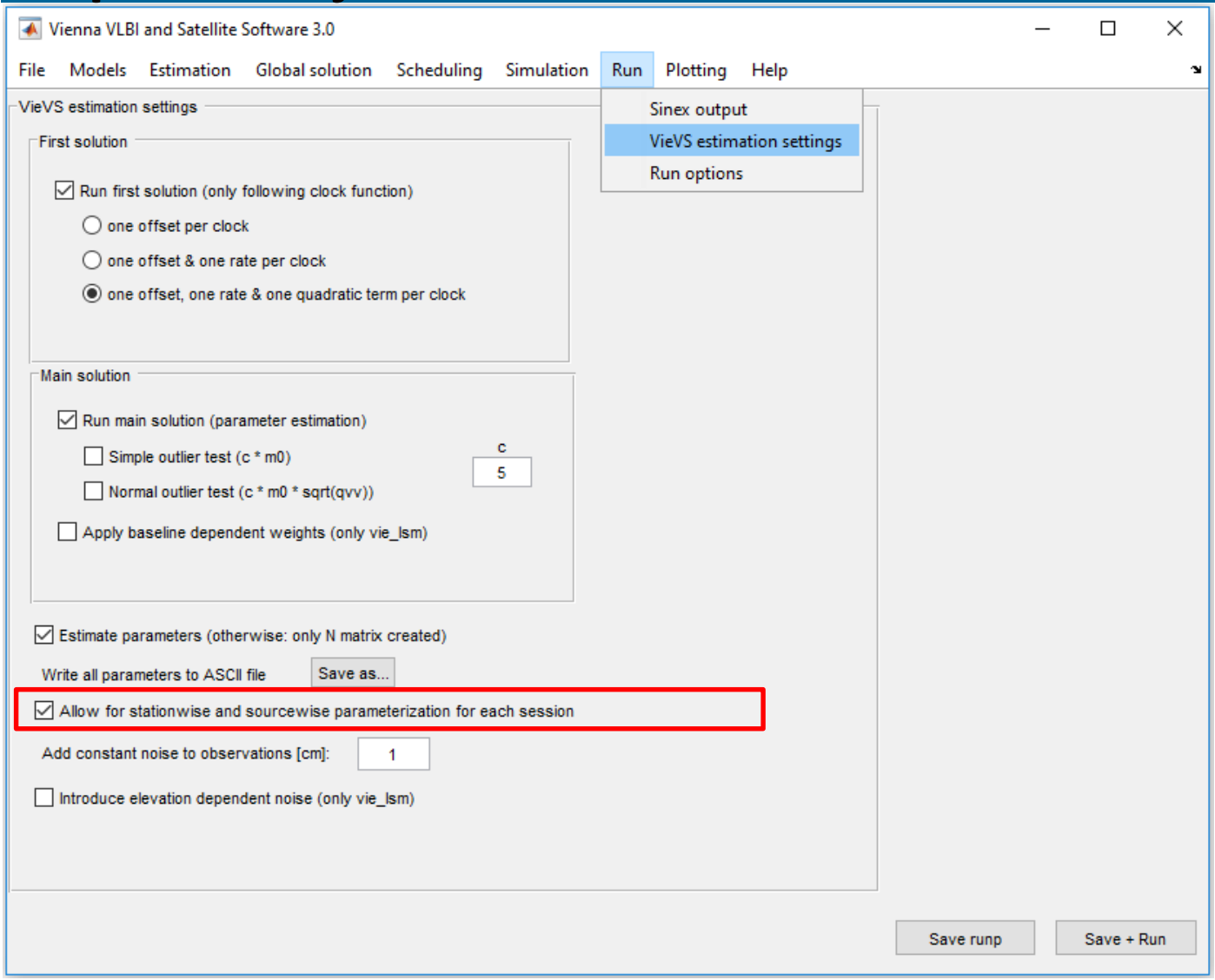
Thanks for your attention!

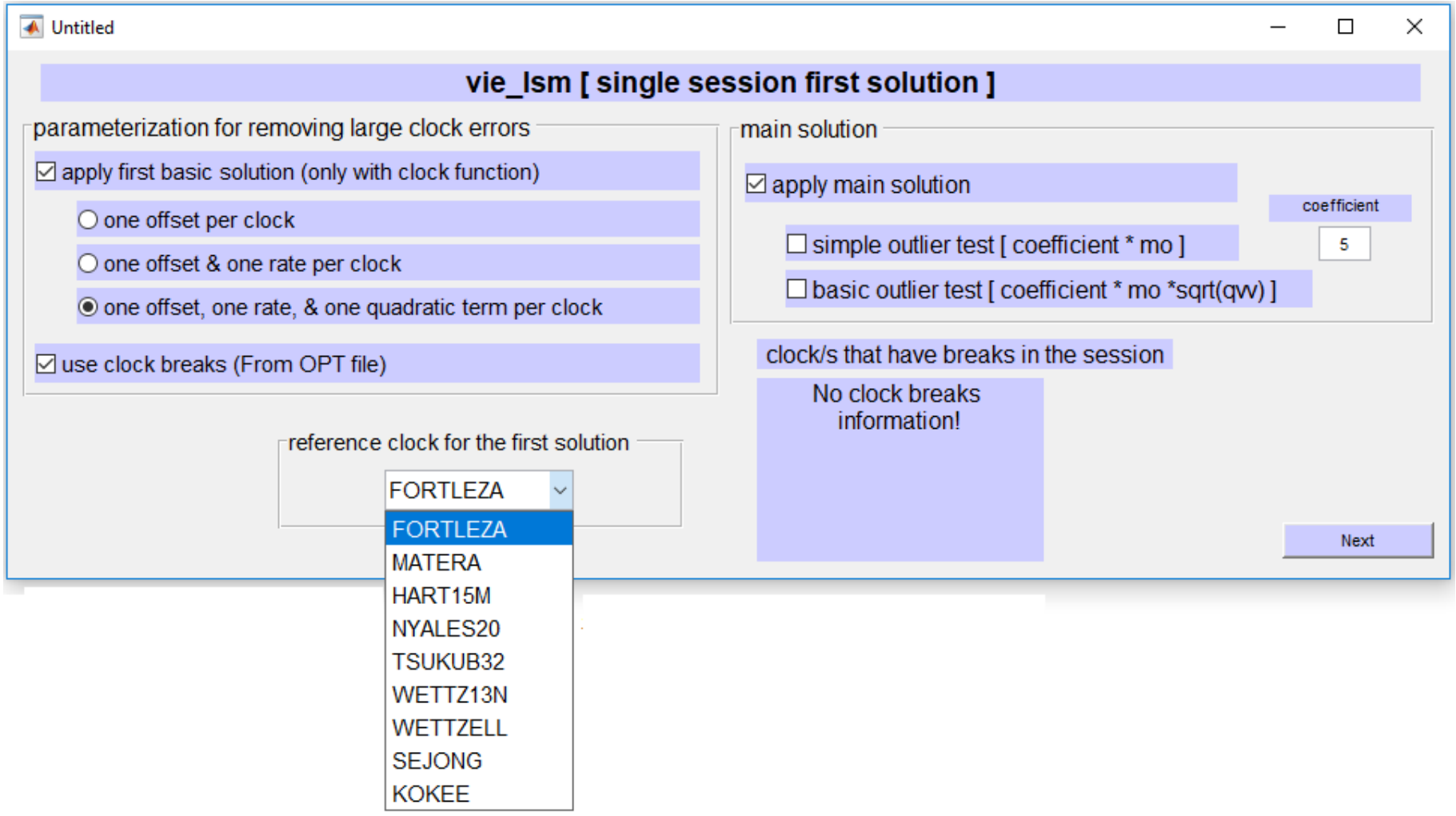
Appendices

(Station- and source-wise parameterisation of least-squares adjustment in VieVS)

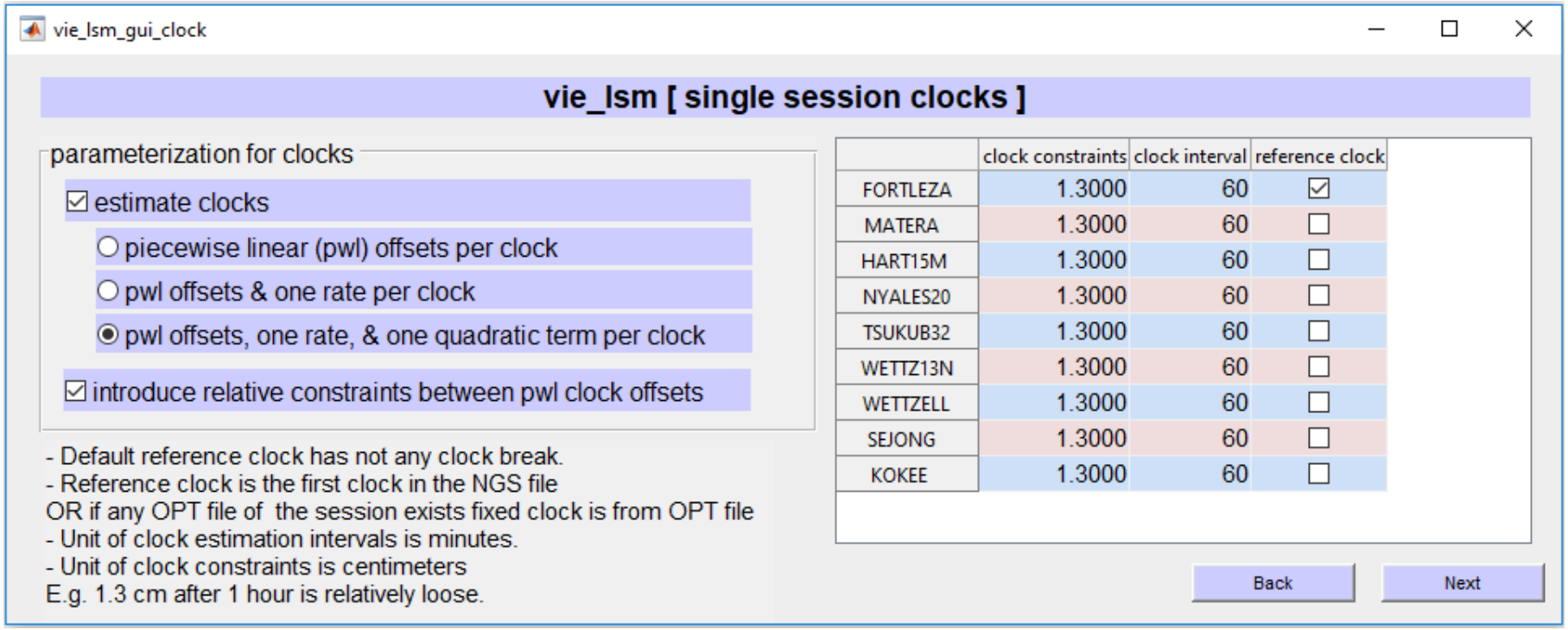
A.1. Station- and source-wise parameterisation of least-squares adjustment in VieVS



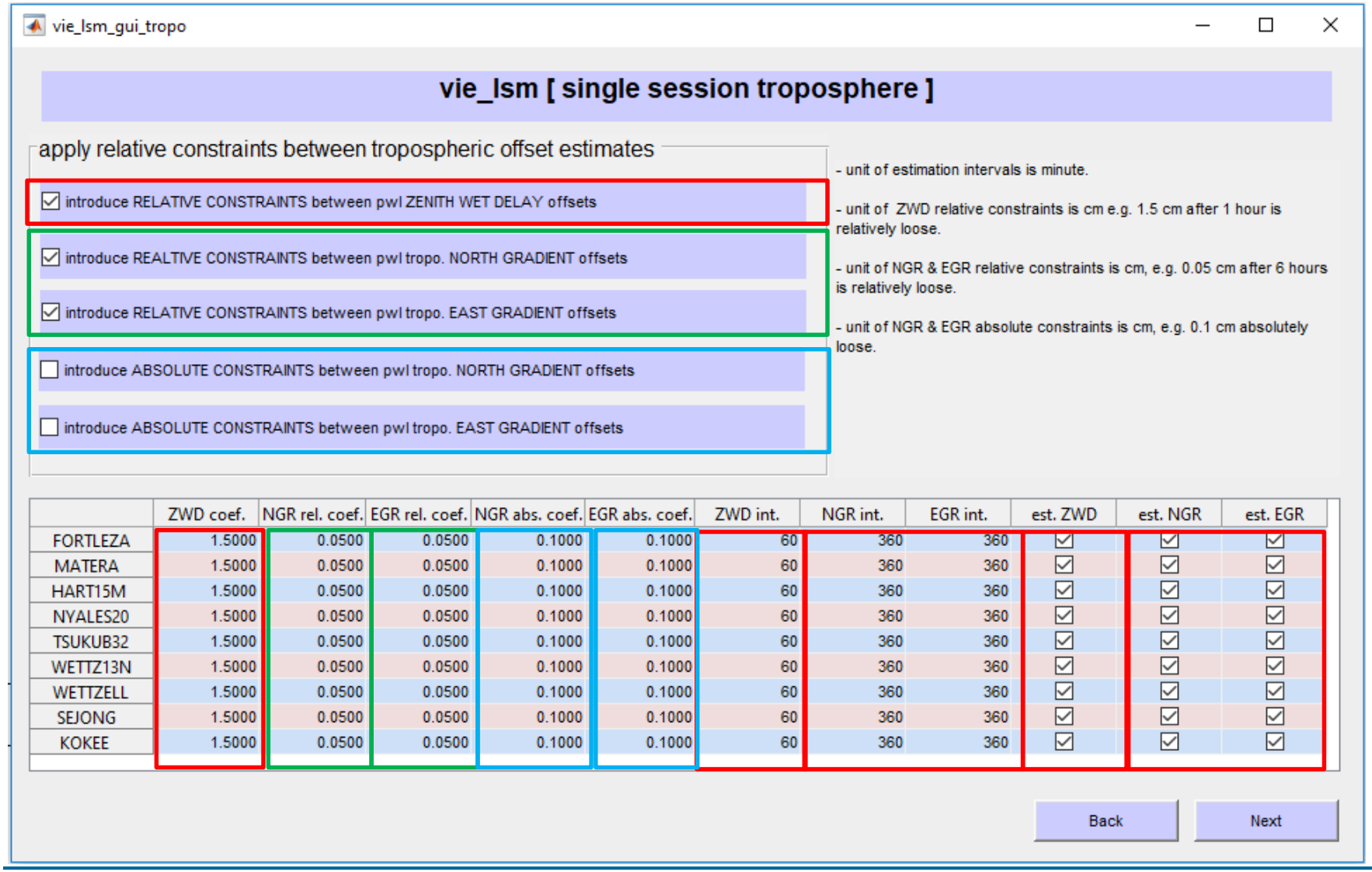
A.1.1. Clock-wise parameterisation



A.1.1. Clock-wise parameterisation



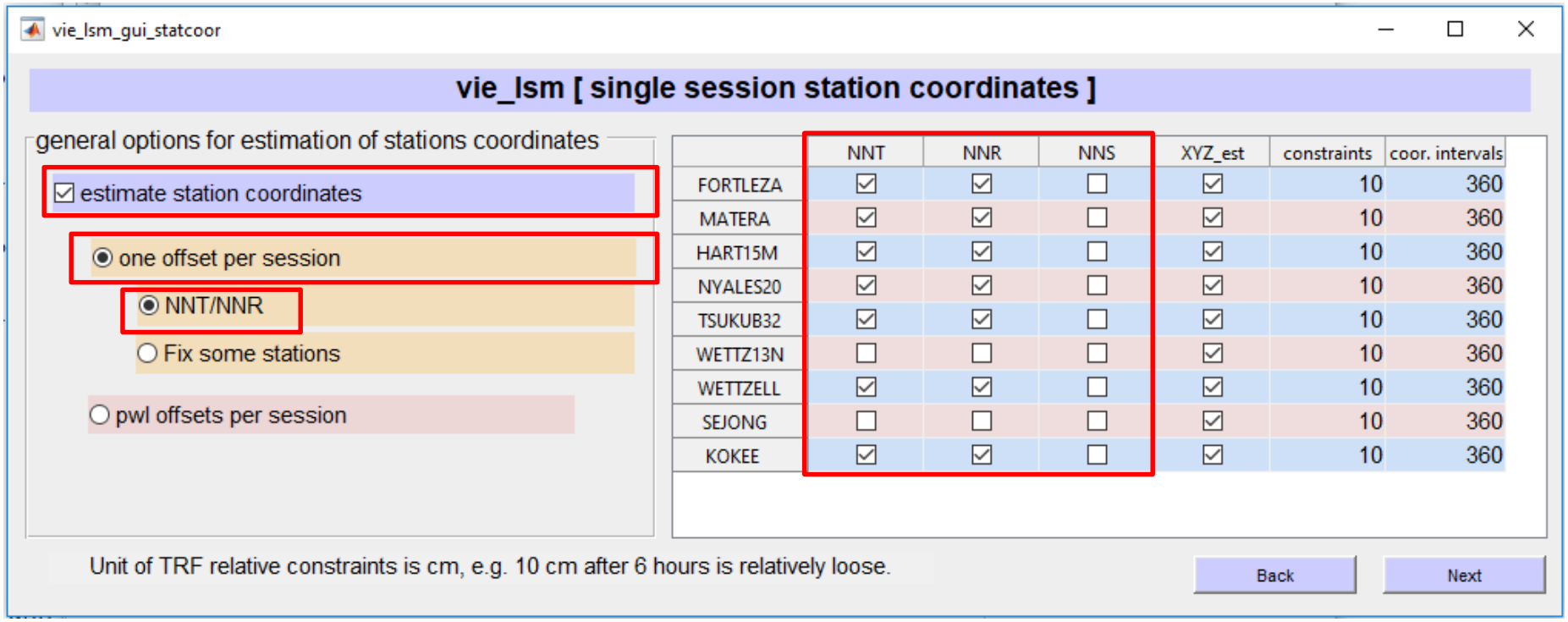
A.1.2. Station-wise troposphere delay parameterisation



	ZWD coef.	NGR rel. coef.	EGR rel. coef.	NGR abs. coef.	EGR abs. coef.	ZWD int.	NGR int.	EGR int.	est. ZWD	est. NGR	est. EGR
FORTLEZA	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
MATERA	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
HART15M	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
NYALES20	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
TSUKUB32	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
WETTZ13N	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
WETTZELL	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
SEJONG	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑
KOKEE	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	☑	☑	☑

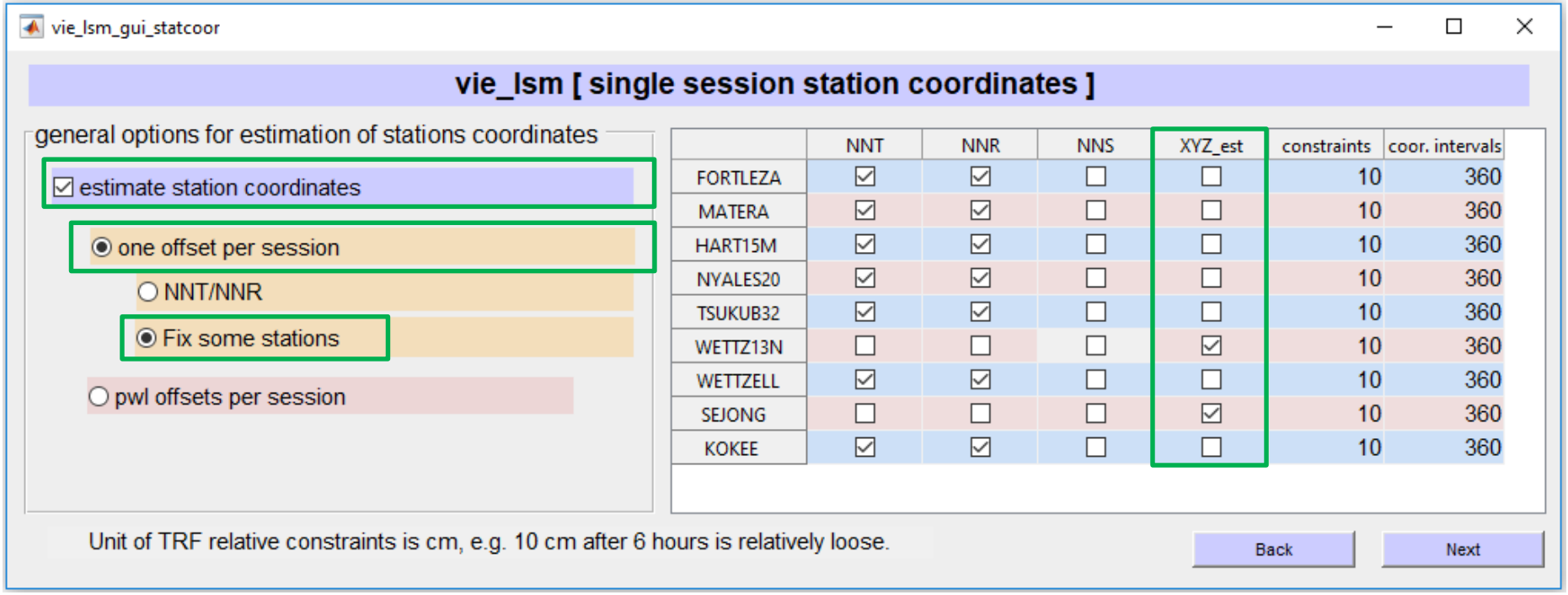
A.1.3. Selecting TRF datum stations to introduce NNT/NNR

Case 1: NNT/NNR
(one coordinate offset per session)



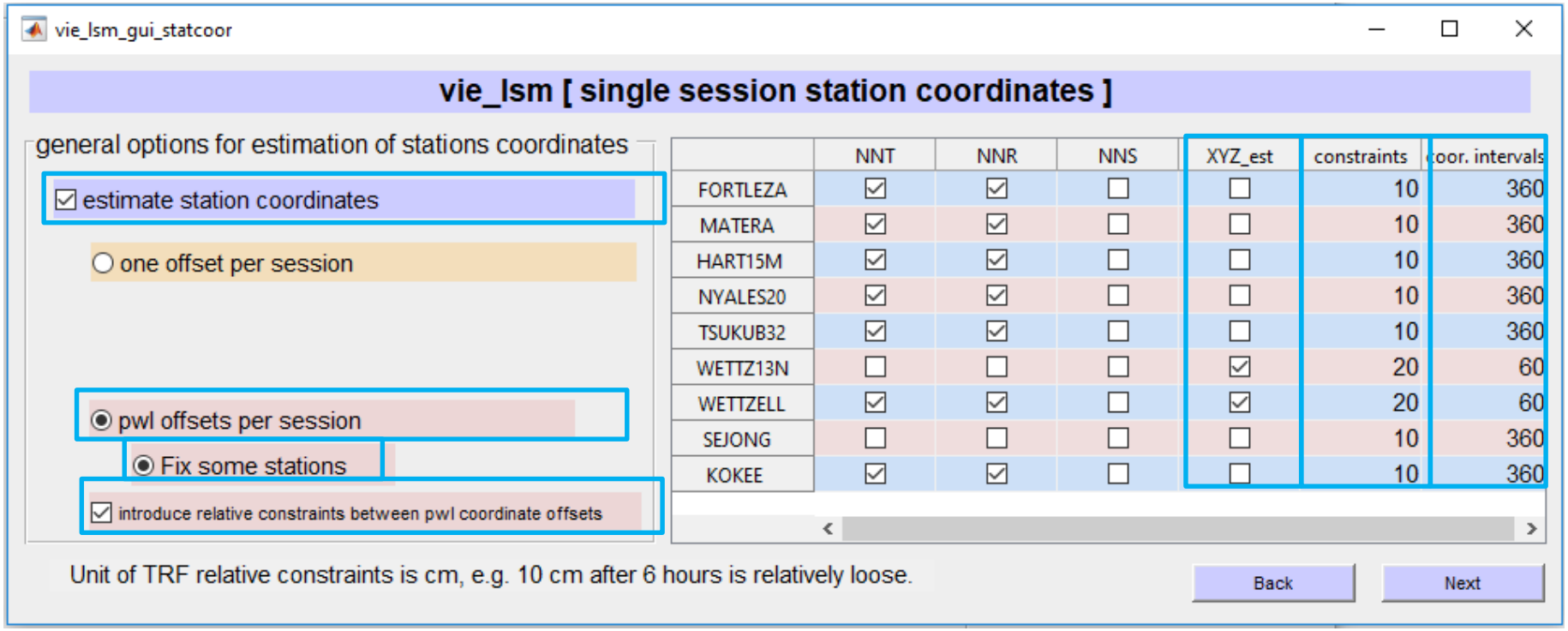
A.1.4. Selecting TRF datum stations to fix a priori coordinates

Case 2: Fix some station coordinates
(one coordinate offset per session)



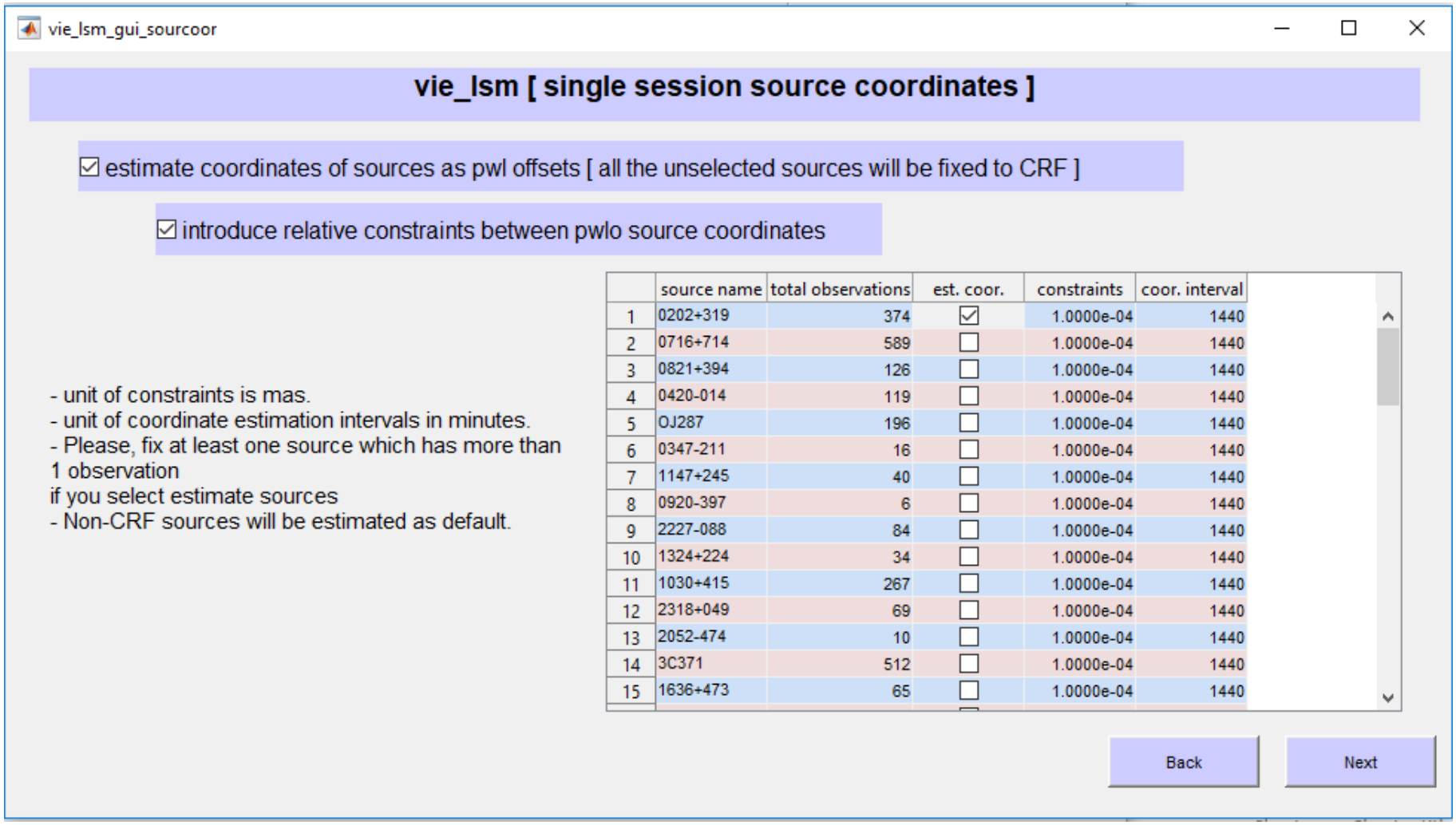
A.1.5. Estimating sub-daily station coordinates as PWLO

Case 3: Fix some station coordinates
(estimate sub-daily TRF coordinates as CPWLO)



	NNT	NNR	NNS	XYZ_est	constraints	coor. intervals
FORTLEZA	☑	☑	☐	☐	10	360
MATERA	☑	☑	☐	☐	10	360
HART15M	☑	☑	☐	☐	10	360
NYALES20	☑	☑	☐	☐	10	360
TSUKUB32	☑	☑	☐	☐	10	360
WETTZ13N	☐	☐	☐	☑	20	60
WETTZELL	☑	☑	☐	☑	20	60
SEJONG	☐	☐	☐	☐	10	360
KOKEE	☑	☑	☐	☐	10	360

A.1.6. Source-wise parameterisation



	source name	total observations	est. coor.	constraints	coor. interval
1	0202+319	374	☑	1.0000e-04	1440
2	0716+714	589	☐	1.0000e-04	1440
3	0821+394	126	☐	1.0000e-04	1440
4	0420-014	119	☐	1.0000e-04	1440
5	OJ287	196	☐	1.0000e-04	1440
6	0347-211	16	☐	1.0000e-04	1440
7	1147+245	40	☐	1.0000e-04	1440
8	0920-397	6	☐	1.0000e-04	1440
9	2227-088	84	☐	1.0000e-04	1440
10	1324+224	34	☐	1.0000e-04	1440
11	1030+415	267	☐	1.0000e-04	1440
12	2318+049	69	☐	1.0000e-04	1440
13	2052-474	10	☐	1.0000e-04	1440
14	3C371	512	☐	1.0000e-04	1440
15	1636+473	65	☐	1.0000e-04	1440

A.1.7. vie_lsm single session output parameterisation for global solution