Vie_LSM_V22

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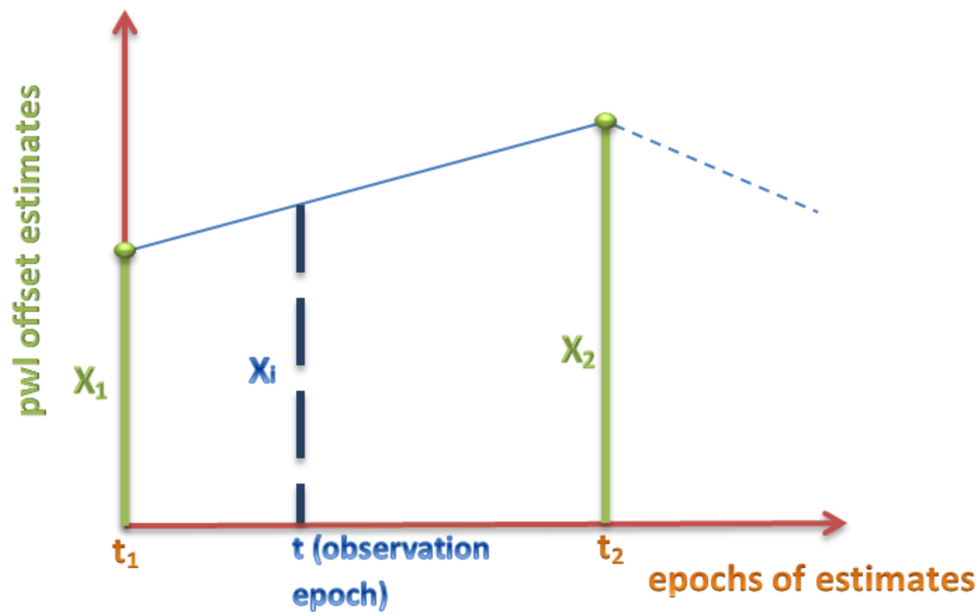
Introduction

- “vie_lsm” is a module of “VieVS”, which estimates geodetic parameters with 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.

Estimated parameters per session are:

- Clocks (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 (NNT + NNR) or as PWLO,
- Source coordinates in CRF (declinations in mas and right ascensions in ms) as one offset per session (NNR) or as PWLO.

PWLO function



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

Partial derivatives of the delay model w.r.t. a parameter's first and second offset

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

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

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

Least-Squares Adjustment in vie_lsm_v22

$$A = \begin{bmatrix} A(1).sm & \cdots & A(15).sm \end{bmatrix}$$

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)

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

bc is a zero vector (due to NNT and NNR conditions)

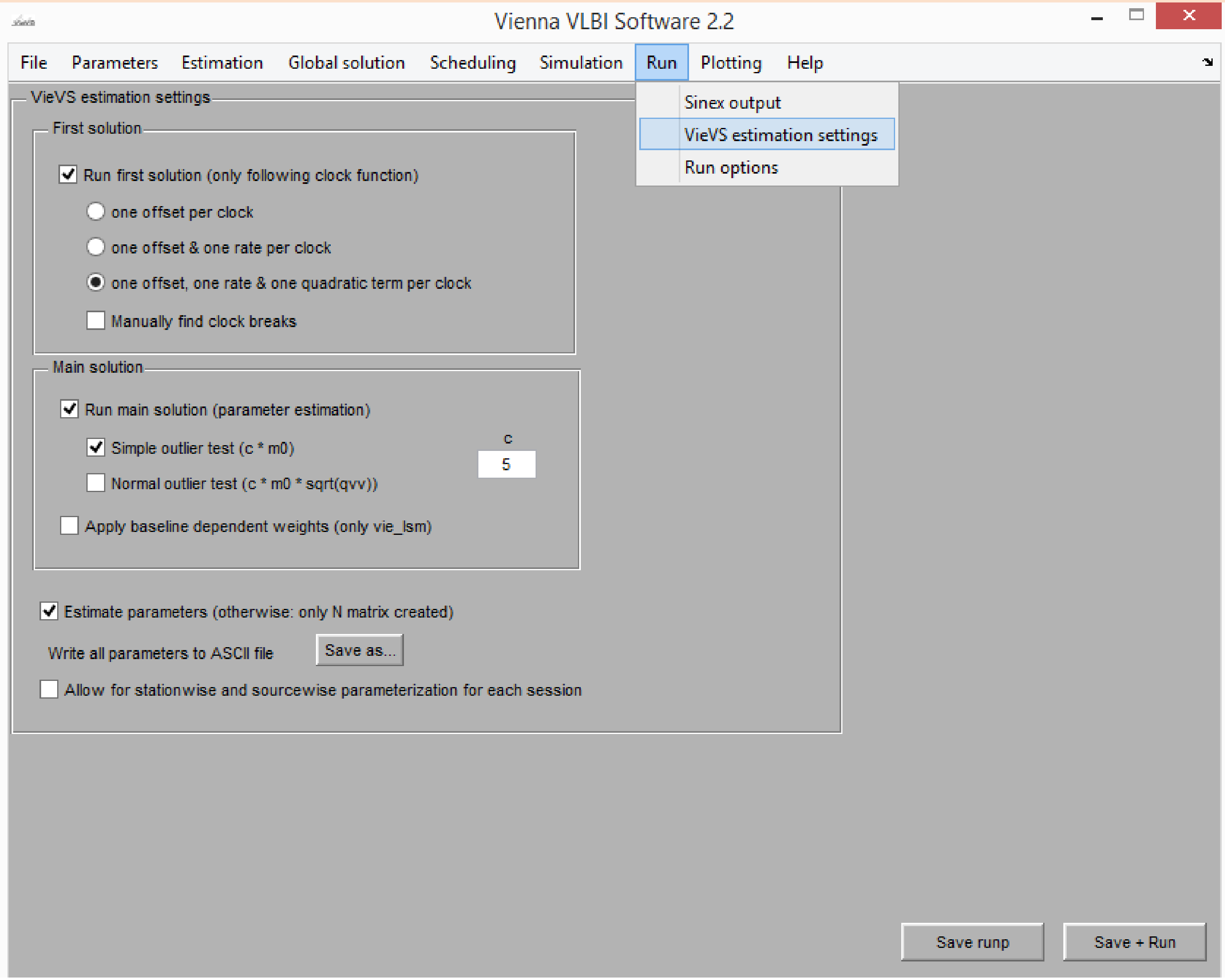
parameter vector (estimates)

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

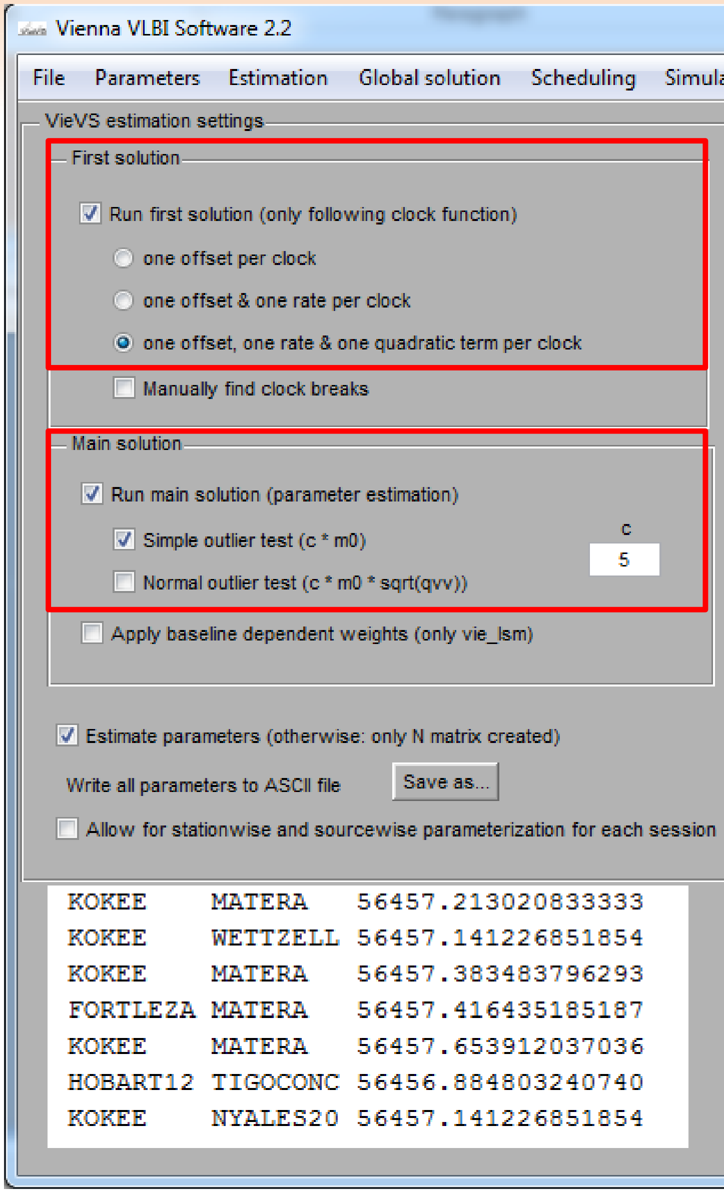
$$K_x = m_0 N^-$$

variance-covariance matrix of the estimates

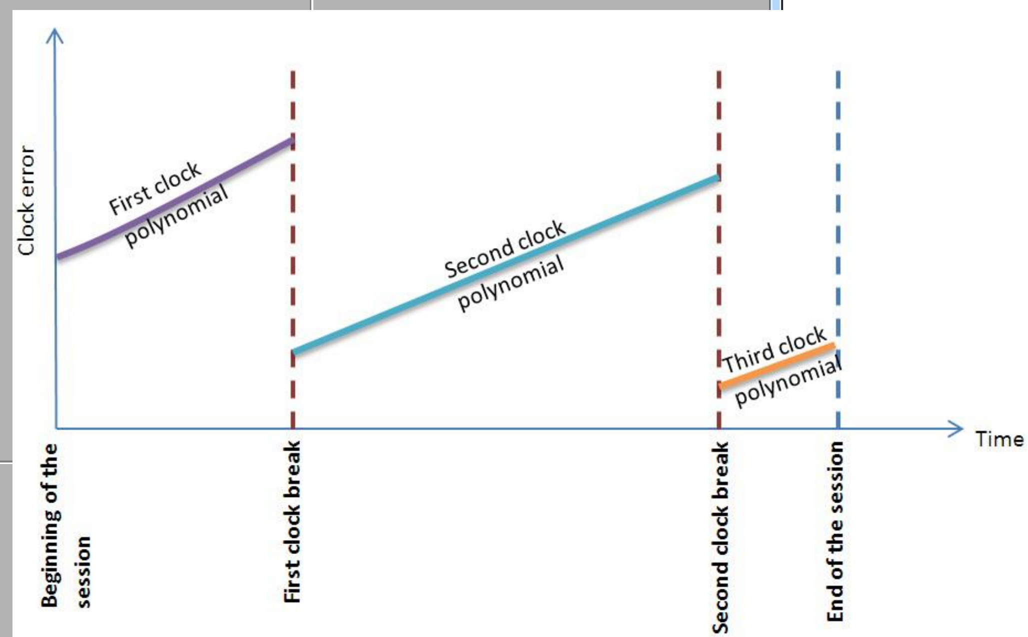
Reducing large clock errors and correcting clock breaks in a first least-sqaures solution



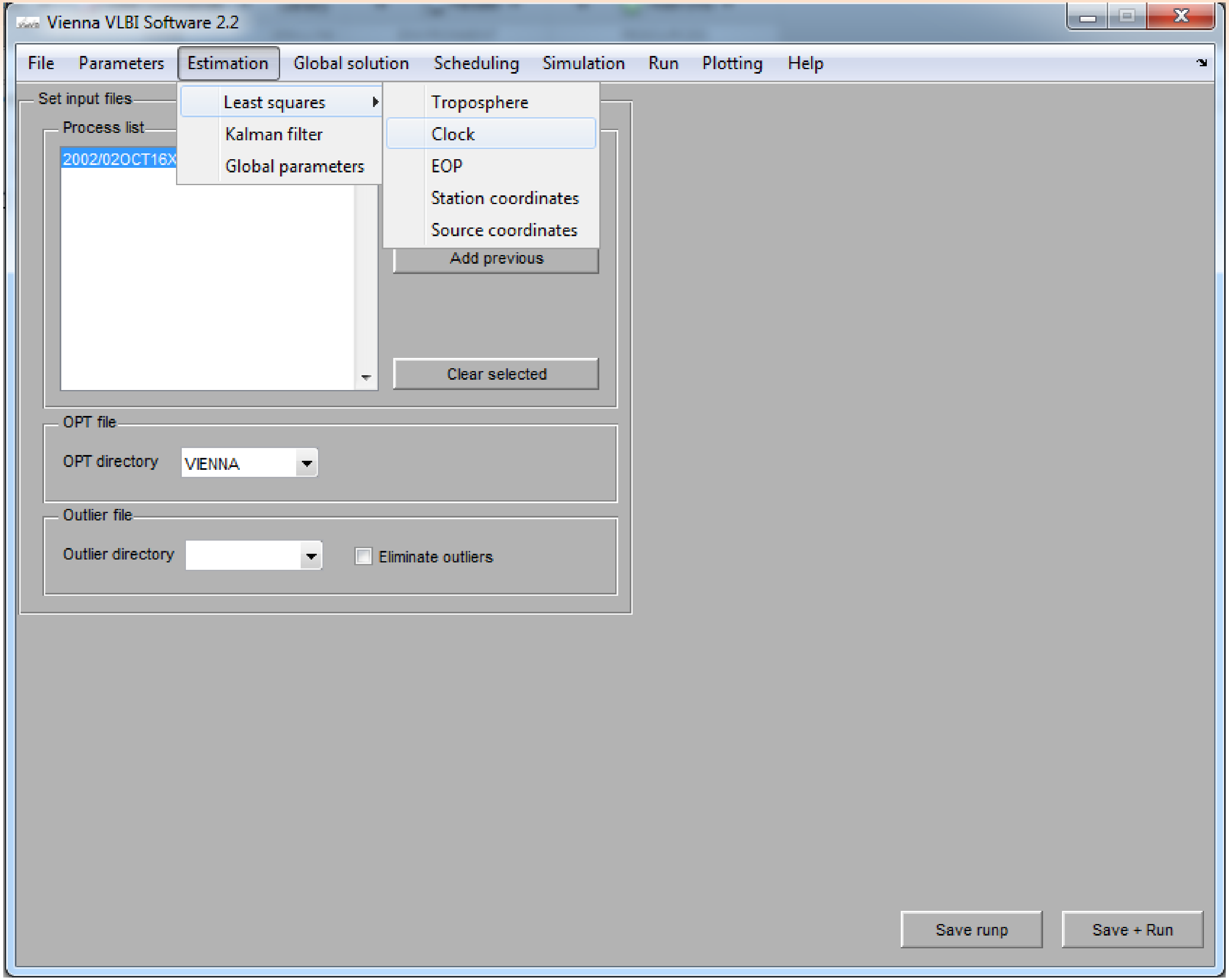
Reducing large clock errors and correcting clock breaks in a first least-sqaures solution



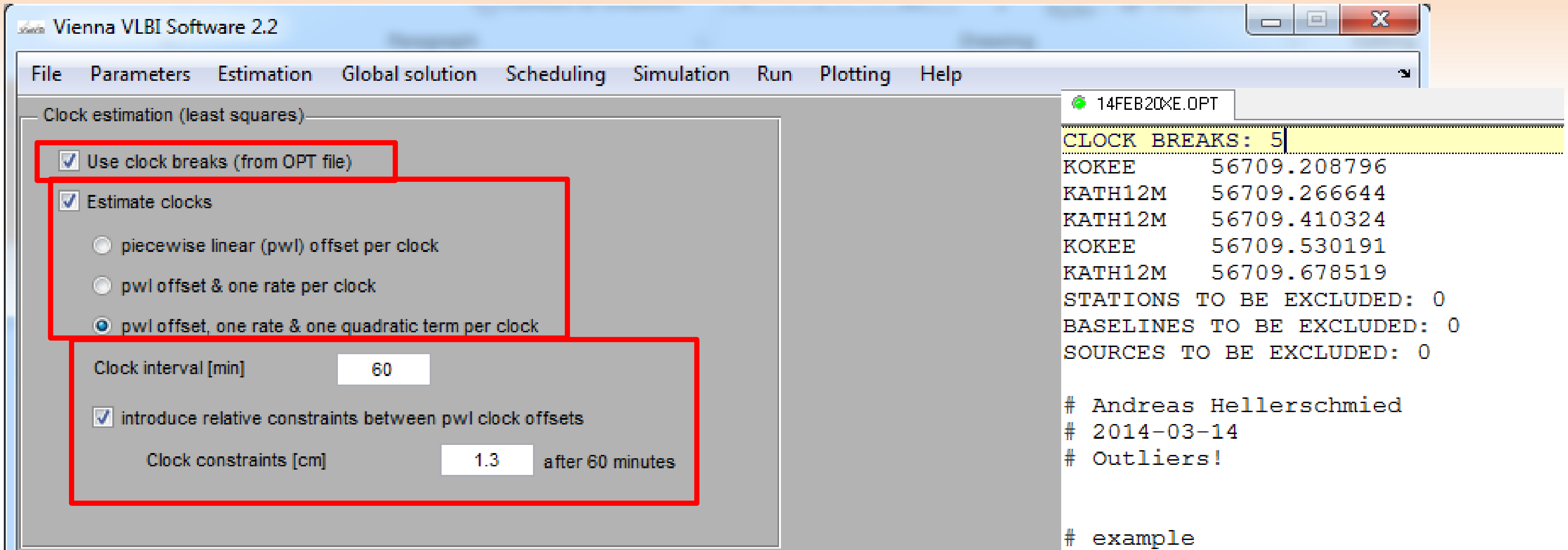
A first LS solution is done for reducing large clock errors from the observations and for fixing clock breaks.

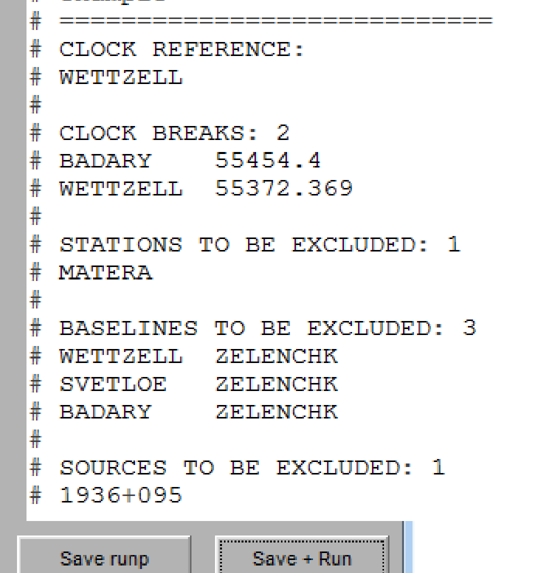


Parameterisation of Least-Squares Adjustment in VieVS



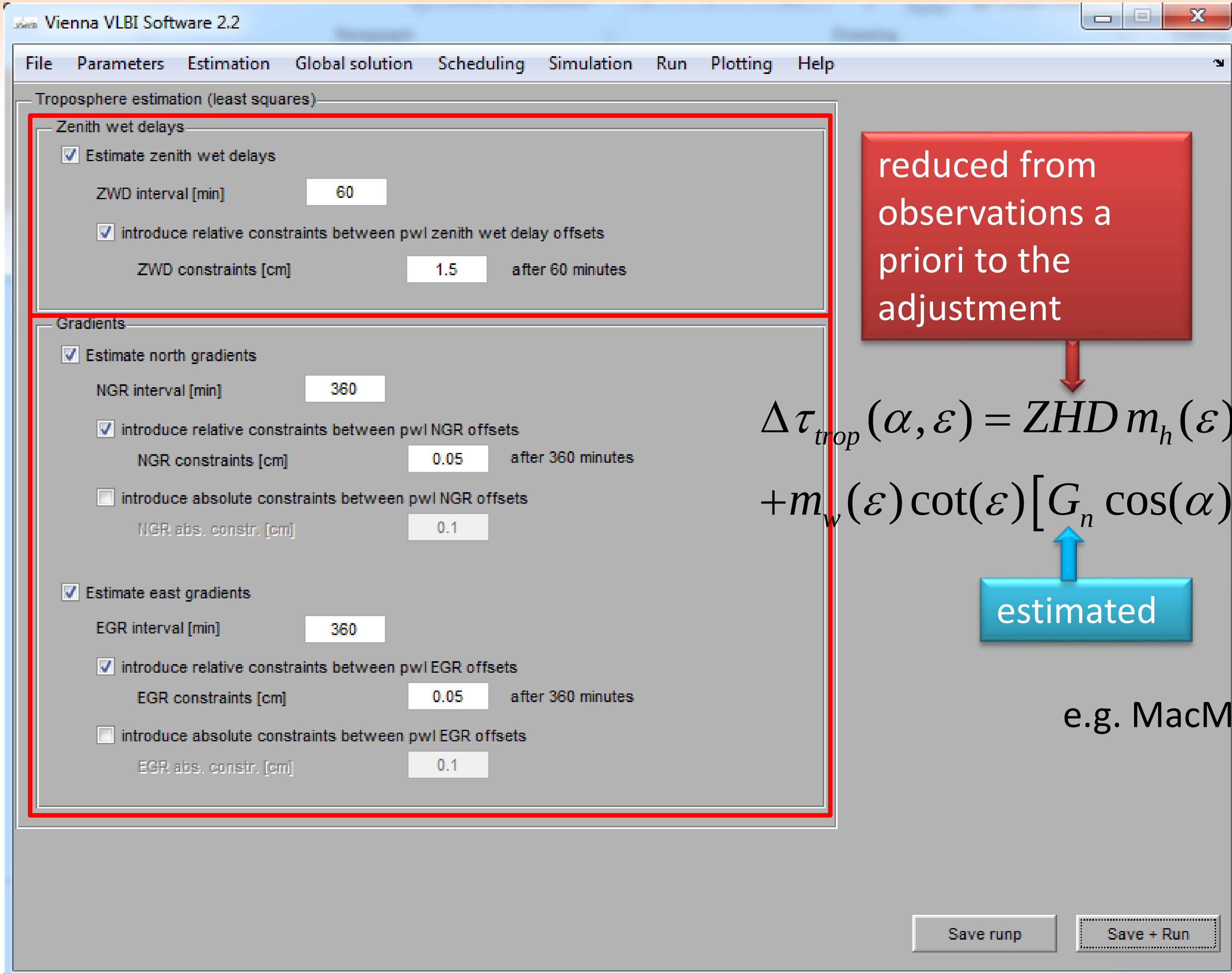
Clocks
(Coefficients of a quadratic function and PWLO)





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 ± a certain standard deviation σ. These constraints are mainly important to bridge gaps without observations to avoid singularity of the normal equation system.

Tropopshere delays
(Zenith wet delays, north and east gradients)



reduced from observations a priori to the adjustment

estimated

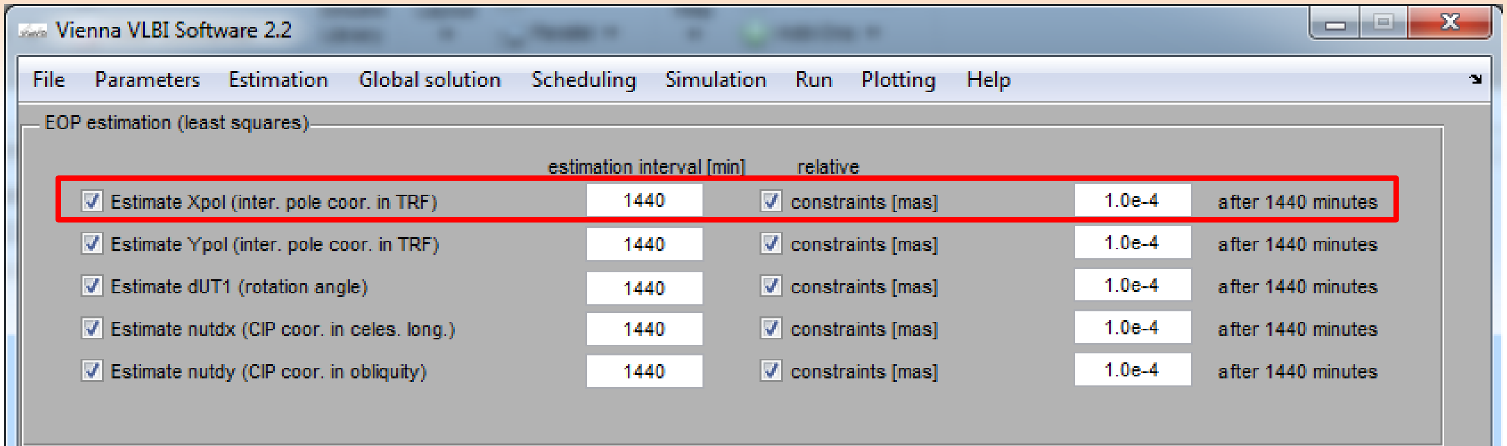
$$\Delta\tau_{trop}(\alpha,\varepsilon) = ZHD\, m_h(\varepsilon) + ZWD\, m_w(\varepsilon)$$
$$+ m_w(\varepsilon)\cot(\varepsilon)\left[G_n\cos(\alpha) + G_e\sin(\alpha)\right]$$

estimated

estimated

e.g. MacMillan 1995

Earth Orientation Parameters

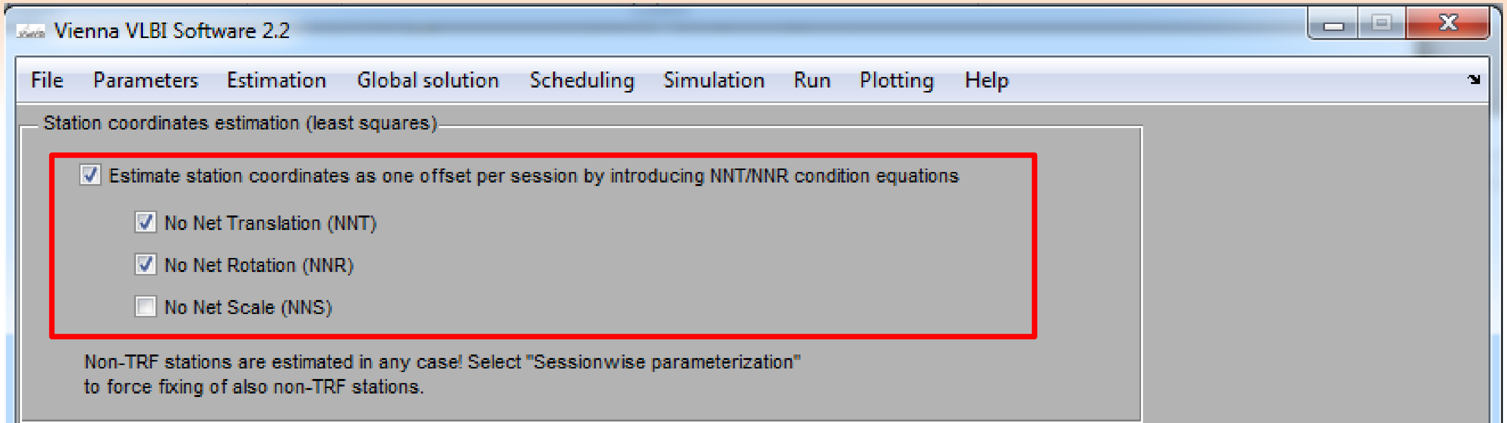


If you want to estimate one constant value per session, the recommendation is to set the parameterization as shown above. Very strong relative constraints of 1e-4 m(a)s/day take care that the estimates are the same over the session.

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.

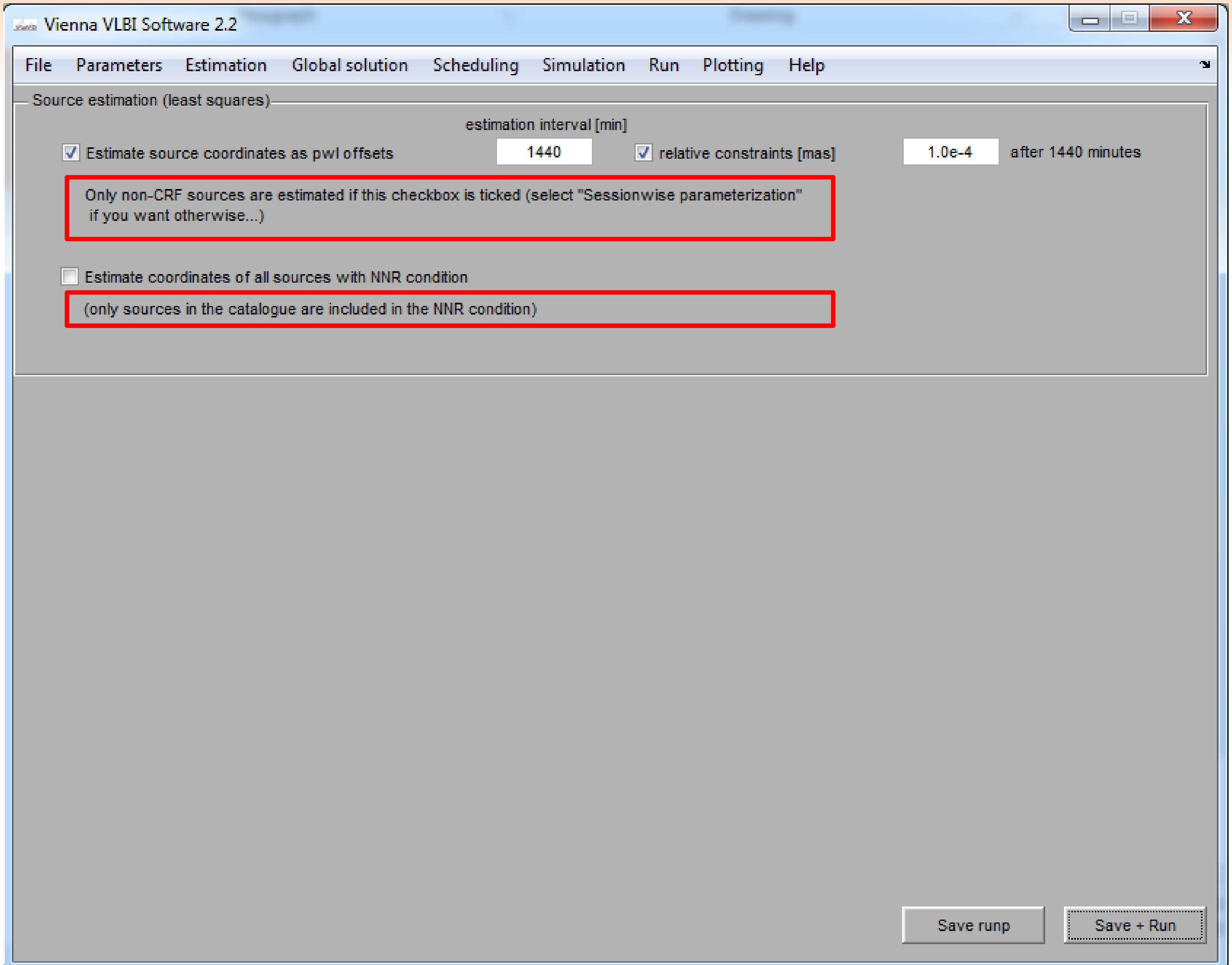
Save runp   Save + Run

Antenna TRF coordinates

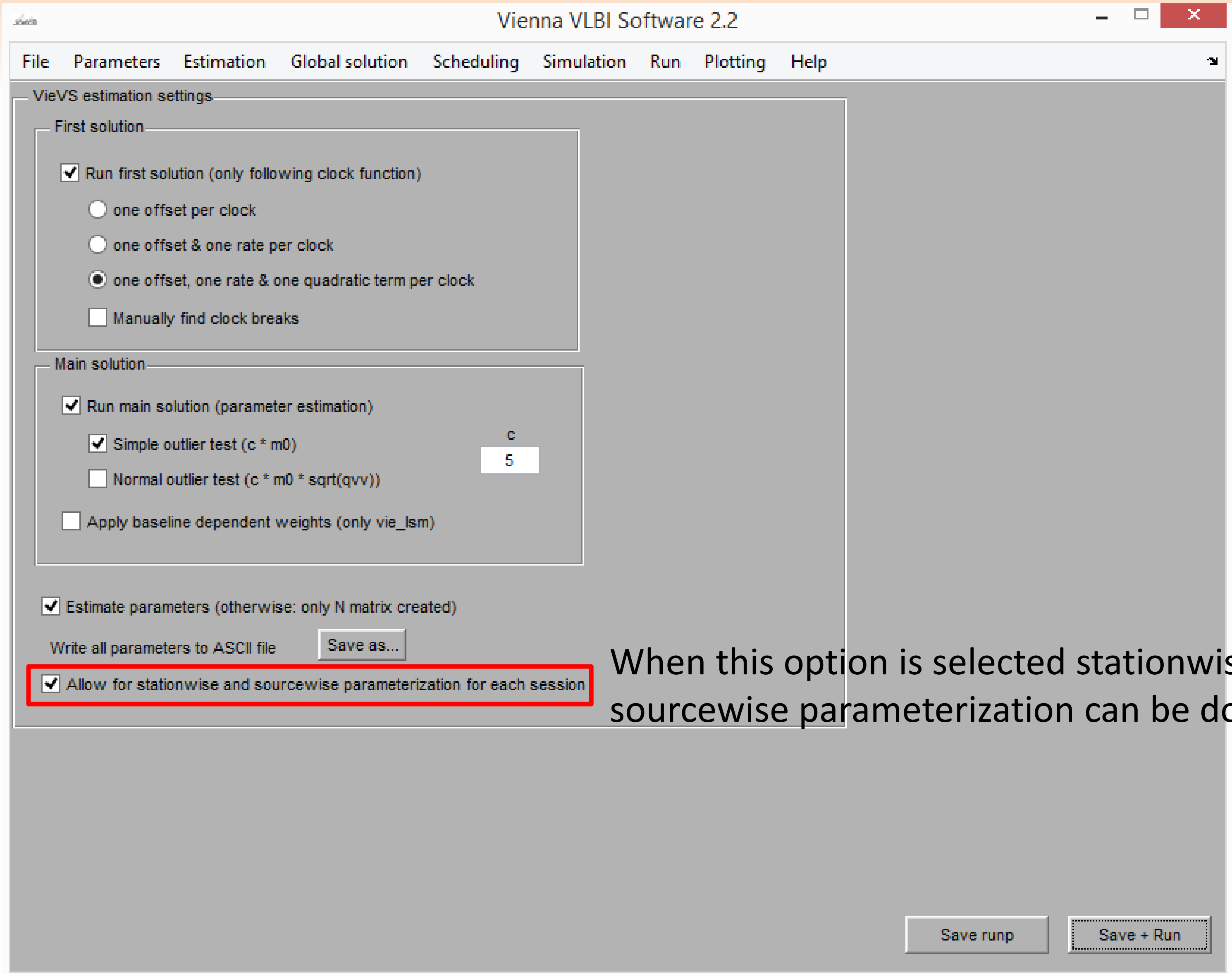


- NNT and NNR conditions are imposed to provide the estimated TRF would neither translate nor rotate w.r.t. the a priori TRF. Thus, 3 translations and 3 rotations between the estimated and a priori TRF will be zero.
- Non-TRF stations will not be a part of the datum when NNT and NNR are introduced!
-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

Source CRF coordinates

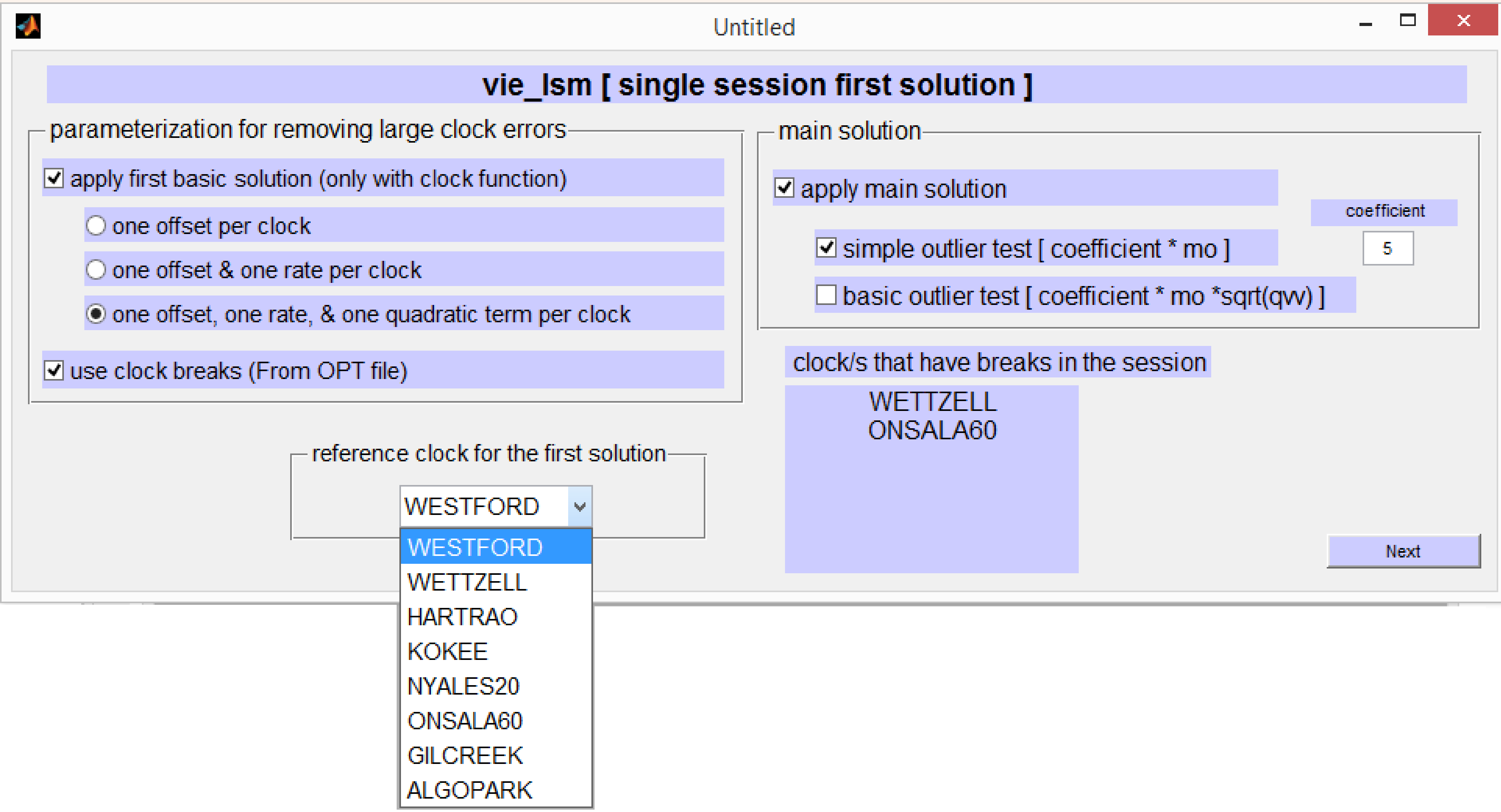


Stationwise and sourcewise parameterization for each session

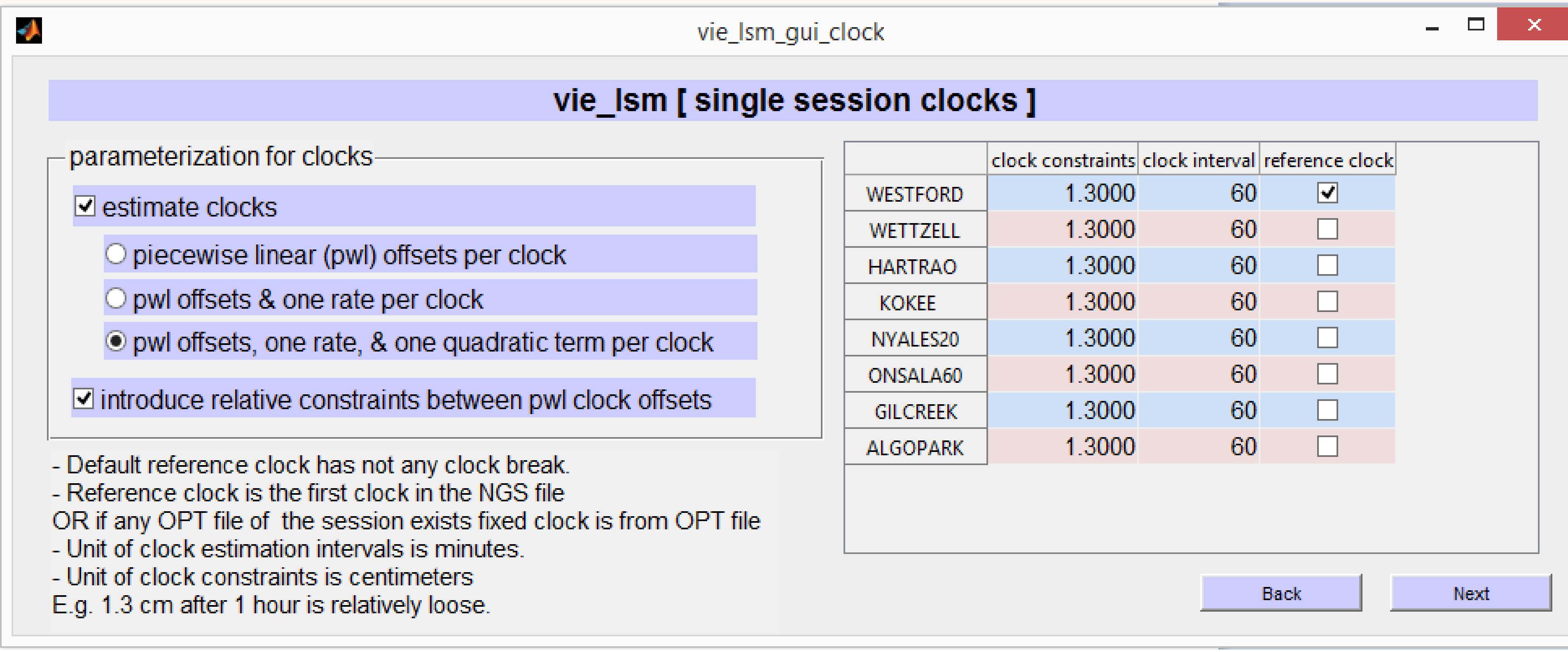


When this option is selected stationwise and sourcewise parameterization can be done!

Reference clock selection for first LS



Stationwise clock parameterization



Stationwise troposphere delay parameterization

vie_lsm_gui_tropo

vie_lsm [single session troposphere]

apply relative constraints between tropospheric offset estimates

- [x] introduce RELATIVE CONSTRAINTS between pwl ZENITH WET DELAY offsets
- [x] introduce REALTIVE CONSTRAINTS between pwl tropo. NORTH GRADIENT offsets
- [x] introduce RELATIVE CONSTRAINTS between pwl tropo. EAST GRADIENT offsets
- [ ] introduce ABSOLUTE CONSTRAINTS between pwl tropo. NORTH GRADIENT offsets
- [ ] introduce ABSOLUTE CONSTRAINTS between pwl tropo. EAST GRADIENT offsets

- unit of estimation intervals is minute.

- unit of ZWD relative constraints is cm e.g. 1.5 cm after 1 hour is relatively loose.

- unit of NGR & EGR relative constraints is cm, e.g. 0.05 cm after 6 hours is relatively loose.

- unit of NGR & EGR absolute constraints is cm, e.g. 0.1 cm absolutely loose.

	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
WESTFORD	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	✓	✓	✓
HARTRAO	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	✓	✓	✓
NYALES20	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	✓	✓	✓
ONSALA60	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	✓	✓	✓
GILCREEK	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	✓	✓	✓
ALGOPARK	1.5000	0.0500	0.0500	0.1000	0.1000	60	360	360	✓	✓	✓

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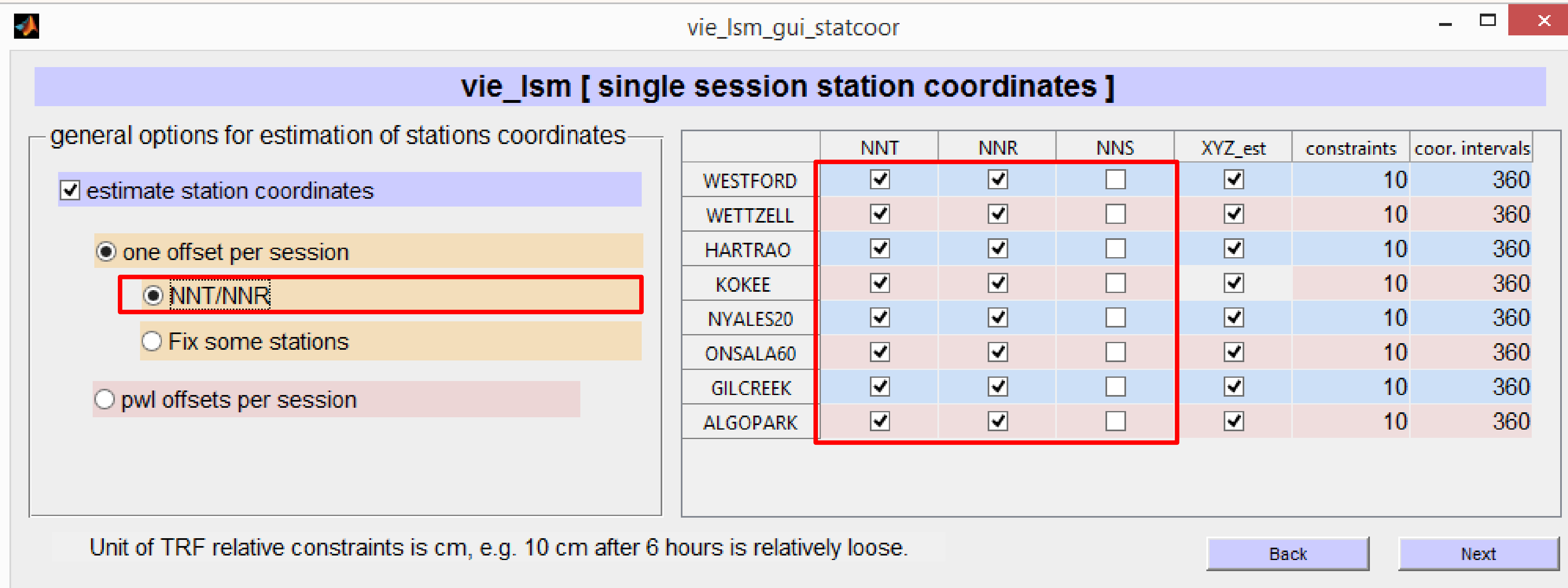
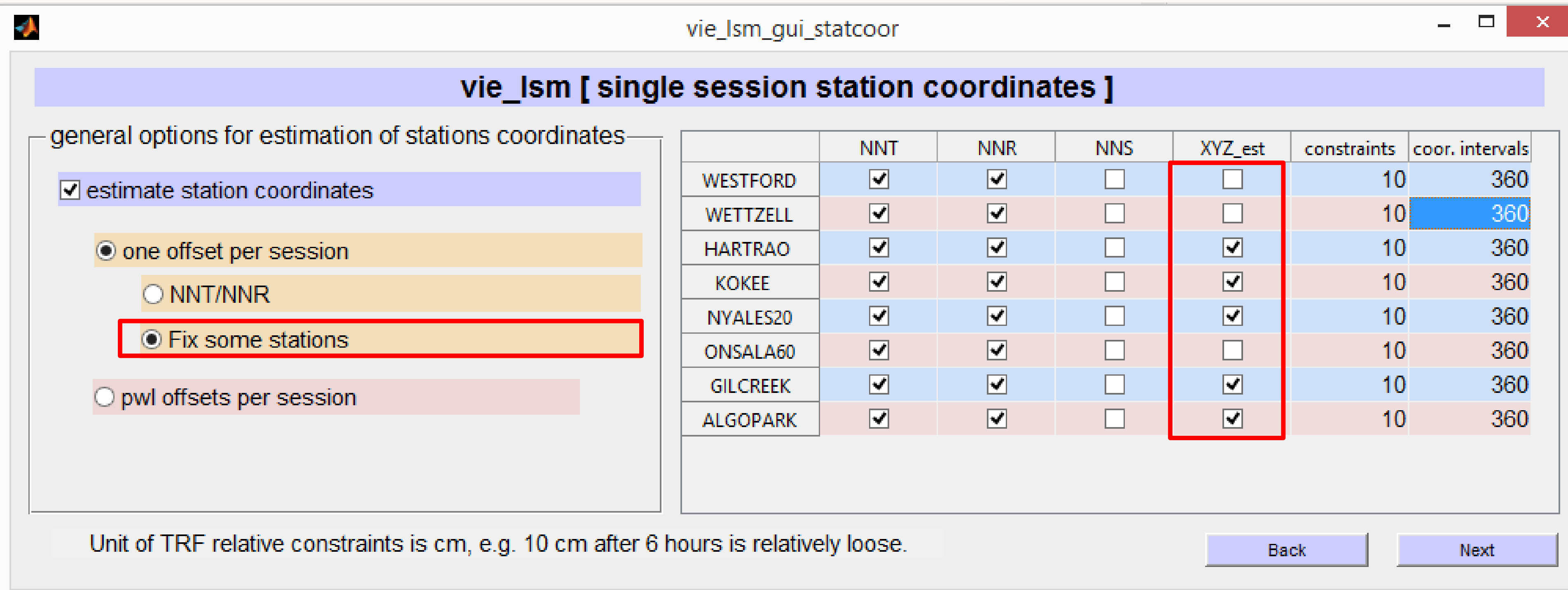
$ZWD(t2)-ZWD(t1)=0\pm\sigma$ cm $NGR(ti)=0\pm\sigma$ cm

$NGR(t2)-NGR(t1)=0\pm\sigma$ cm

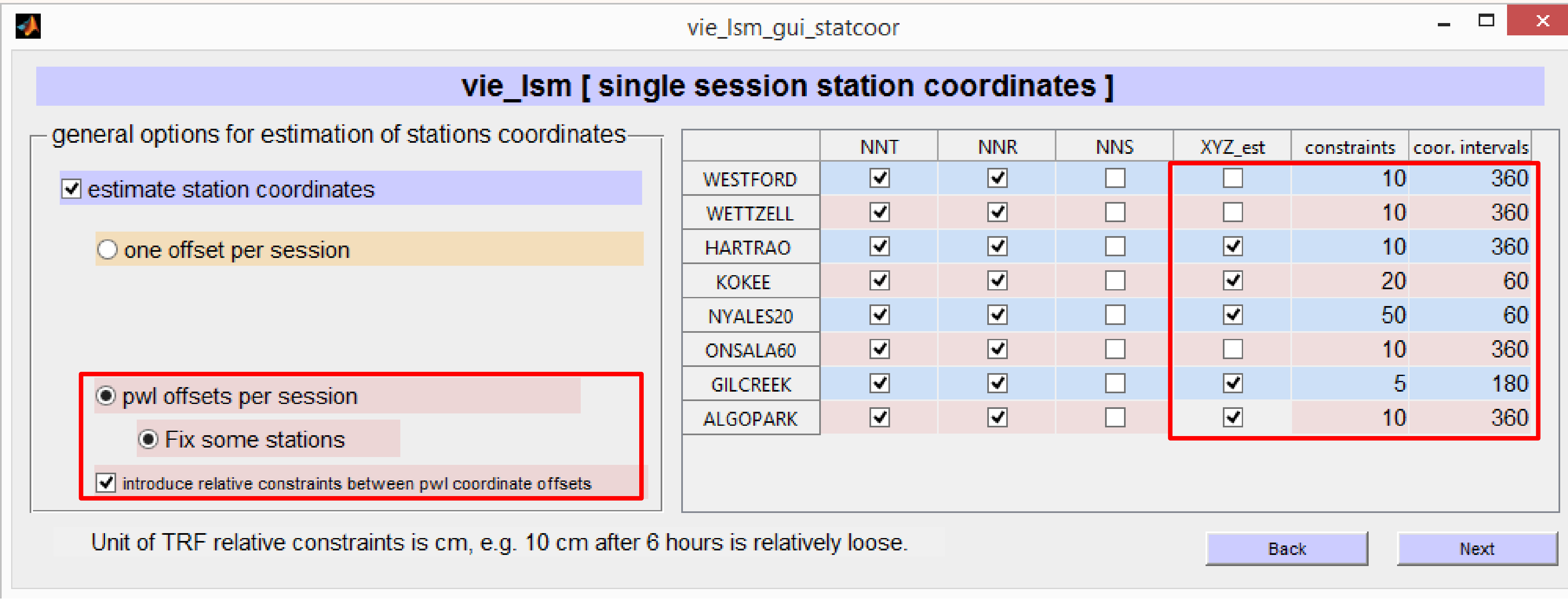
Antenna TRF coordinates are estimated as one offset per session (NNT and NNR constraints on some of the antenna coordinates)



Antenna TRF coordinates are estimated as one offset per session (some antenna coordinates are fixed to their apriori coordinates)



Antenna TRF coordinates as PWLO



In this option,

- Troposphere delays and antenna TRF positions are highly correlated, e.g. for 1h or 2h segments, caused by inhomogeneous sky distribution of the observations. Due to this large correlations, troposphere delays propagate into antenna positions in parameter estimation.

Source CRF coordinates as PWLO

vie_lsm_gui_sourcoor

vie_lsm [single session source coordinates]

☑ estimate coordinates of sources as pwl offsets [all the unselected sources will be fixed to CRF]

☑ introduce relative constraints between pwlo source coordinates

- unit of constraints is mas.
- unit of coordinate estimation intervals in minutes.
- Please, fix at least one source which has more than 1 observation if you select estimate sources
- Non-CRF sources will be estimated as default.

	source name	total observations	est. coor.	constraints	coor. interval
13	1606+106	96	☐	1.0000e-04	1440
14	NRAO512	98	☐	1.0000e-04	1440
15	1044+719	17	☐	1.0000e-04	1440
16	0003-066	18	☐	1.0000e-04	1440
17	1219+044	20	☐	1.0000e-04	1440
18	0235+164	146	☐	1.0000e-04	1440
19	0955+476	84	☐	1.0000e-04	1440
20	0823+033	4	☐	1.0000e-04	1440
21	2234+282	89	☐	1.0000e-04	1440
22	1357+769	172	☐	1.0000e-04	1440
23	0743+259	36	☐	1.0000e-04	1440
24	CTA26	60	☐	1.0000e-04	1440
25	0552+398	211	☑	1	60
26	1519-273	6	☐	1.0000e-04	1440
27	1300+580	131	☐	1.0000e-04	1440
28	0048-097	12	☐	1.0000e-04	1440
29	1923+210	18	☐	1.0000e-04	1440

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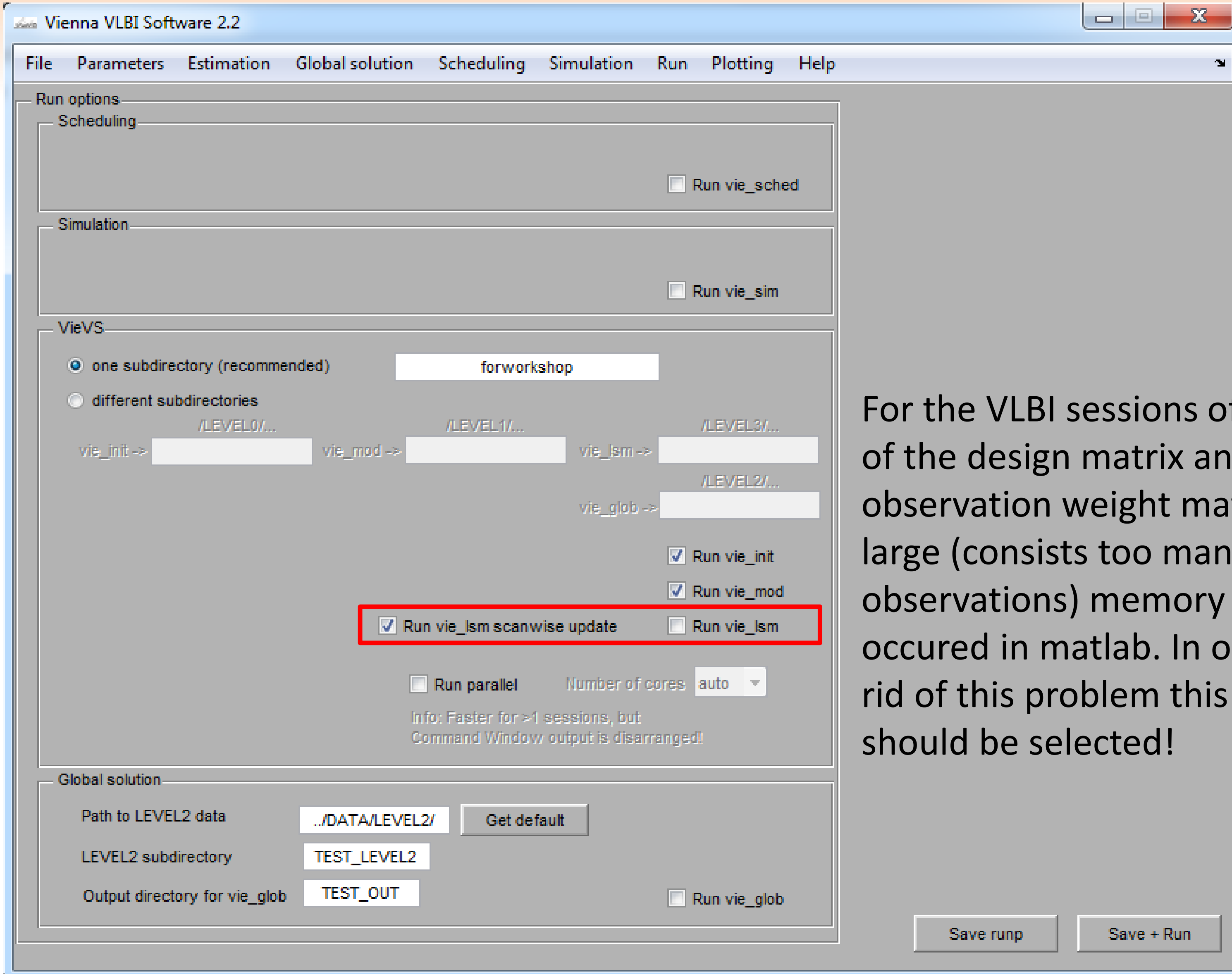
vie_lsm scan-wise update

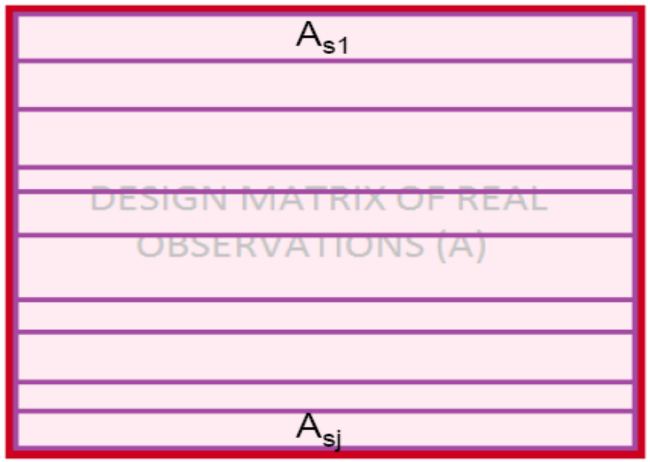


For the VLBI sessions of which size of the design matrix and observation weight matrix is too large (consists too many observations) memory error occured in matlab. In order to get rid of this problem this option should be selected!

Scan-wise update of normal equation system

1 A-matrix per scan

Scan 1



Scan j

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

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

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

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

j : number of scans in the session

$$N = A^T \cdot P \cdot A \quad \rightarrow \quad N = N_A + N_H$$

$$b = A^T \cdot P \cdot oc \quad \rightarrow \quad b = b_A + b_H$$

$$x = N^{-1} \cdot b$$

The work was done by Claudia Tierno Ros. This slide is from her presentation which was prepared for the Third VieVS user workshop, 11-13 September, 2012

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.

Thanks for your attention!