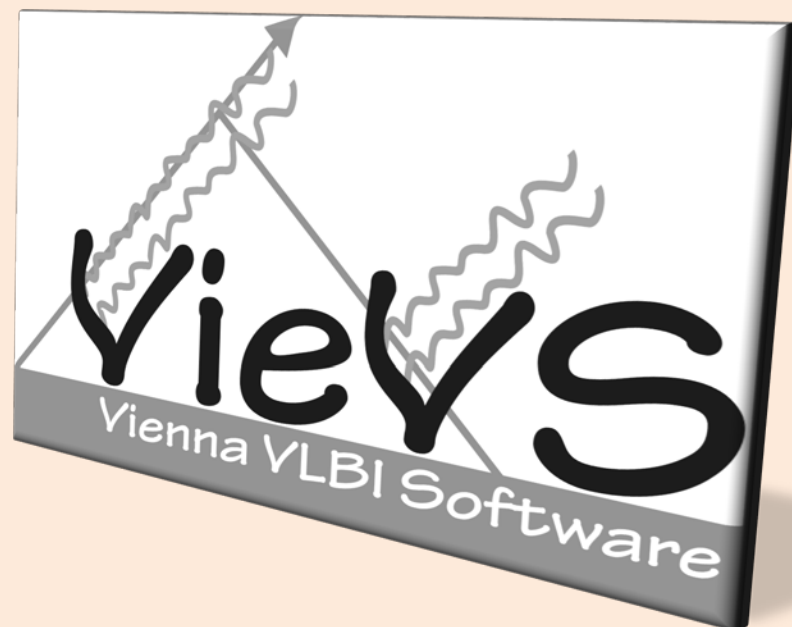


Vie_LSM V2.3 - basics

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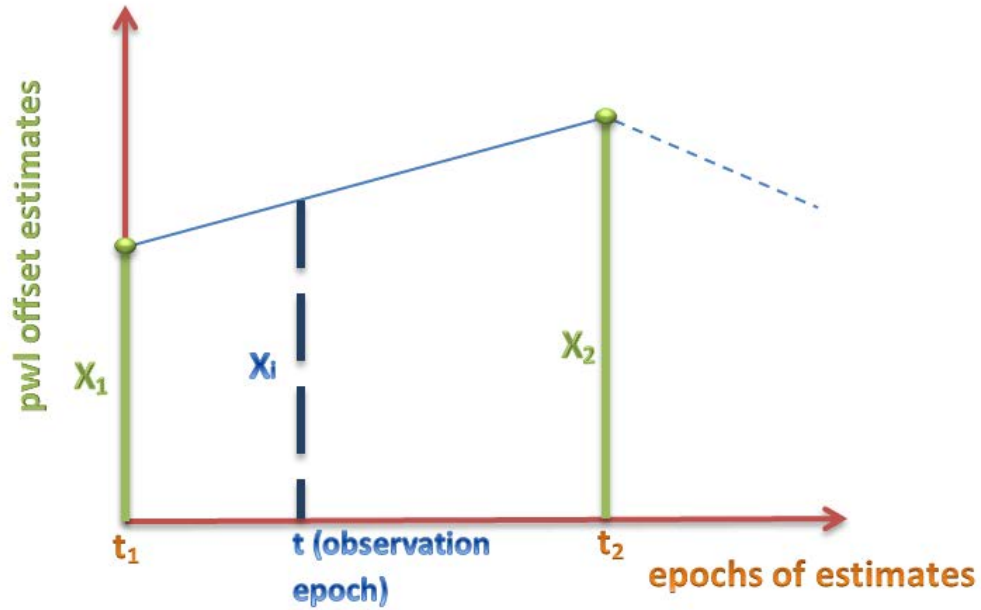
Introduction

- “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/day²), 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.

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_v23

$$A = [A(1).sm \quad \cdots \quad A(15).sm] \quad \rightarrow \quad \text{design matrix of real observation equations}$$

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

$$N = \begin{bmatrix} A^T P A + H^T P_H H & C^T \\ C & 0 \end{bmatrix} \quad b = \begin{bmatrix} A^T P o c + H^T P_H o c h \\ b_c \end{bmatrix} \quad \begin{array}{l} bc \text{ is a zero} \\ \text{vector} \\ \text{(due to NNT} \\ \text{and NNR} \\ \text{conditions)} \end{array}$$

parameter vector
(estimates)

$$x = N^{-1} b \quad m_0 = (v^T P v + v_H^T P_H v_H) / (n_{obs} + n_{constr} - n_{unk})$$

$$K_x = m_0 N^{-1} \quad \rightarrow \quad \text{variance-covariance matrix of the estimates}$$

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

Vienna VLBI Software 2.3

File Models Estimation Global solution Scheduling Simulation Run Plotting Help

VieVS estimation settings

First solution

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

Manually find clock breaks

Main solution

Run main solution (parameter estimation)

Simple outlier test ($c * m0$) c
5

Normal outlier test ($c * m0 * \text{sqrt}(qvv)$)

Apply baseline dependent weights (only vie_ism)

Estimate parameters (otherwise: only N matrix created)

Write all parameters to ASCII file

Allow for stationwise and sourcewise parameterization for each session

A first LS solution is done for reducing large clock errors, new outlier observations are detected and written to text files `VIEWS/DIR/OUTLIER/YOURDIR/YEAR/SESSNAME.OUT` breaks

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

Beginning of the session

First clock break

Second clock break

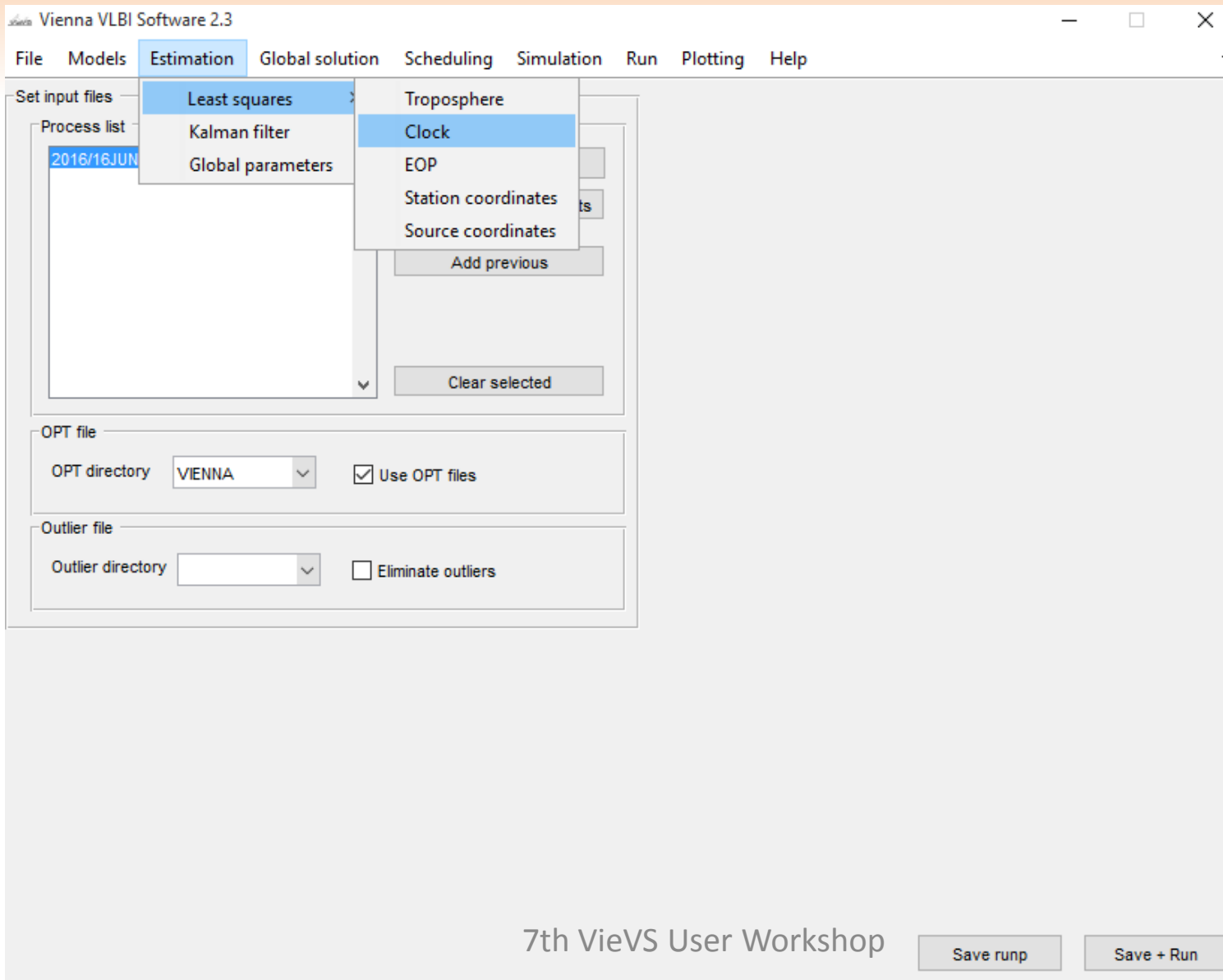
End of the session

Time

polynomial

Third clock polynomial

Parameterisation of Least-Squares Adjustment in VieVS



The screenshot shows the 'Estimation' menu in the Vienna VLBI Software 2.3 interface. The menu is open, showing options for 'Least squares', 'Kalman filter', and 'Global parameters'. The 'Least squares' option is selected, and a sub-menu is visible with options for 'Troposphere', 'Clock', 'EOP', 'Station coordinates', and 'Source coordinates'. The 'Clock' option is highlighted. Below the menu, there are sections for 'OPT file' and 'Outlier file' with dropdown menus and checkboxes.

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Set input files

Process list

2016/16JUN

Least squares

Kalman filter

Global parameters

Troposphere

Clock

EOP

Station coordinates

Source coordinates

Add previous

Clear selected

OPT file

OPT directory VIENNA Use OPT files

Outlier file

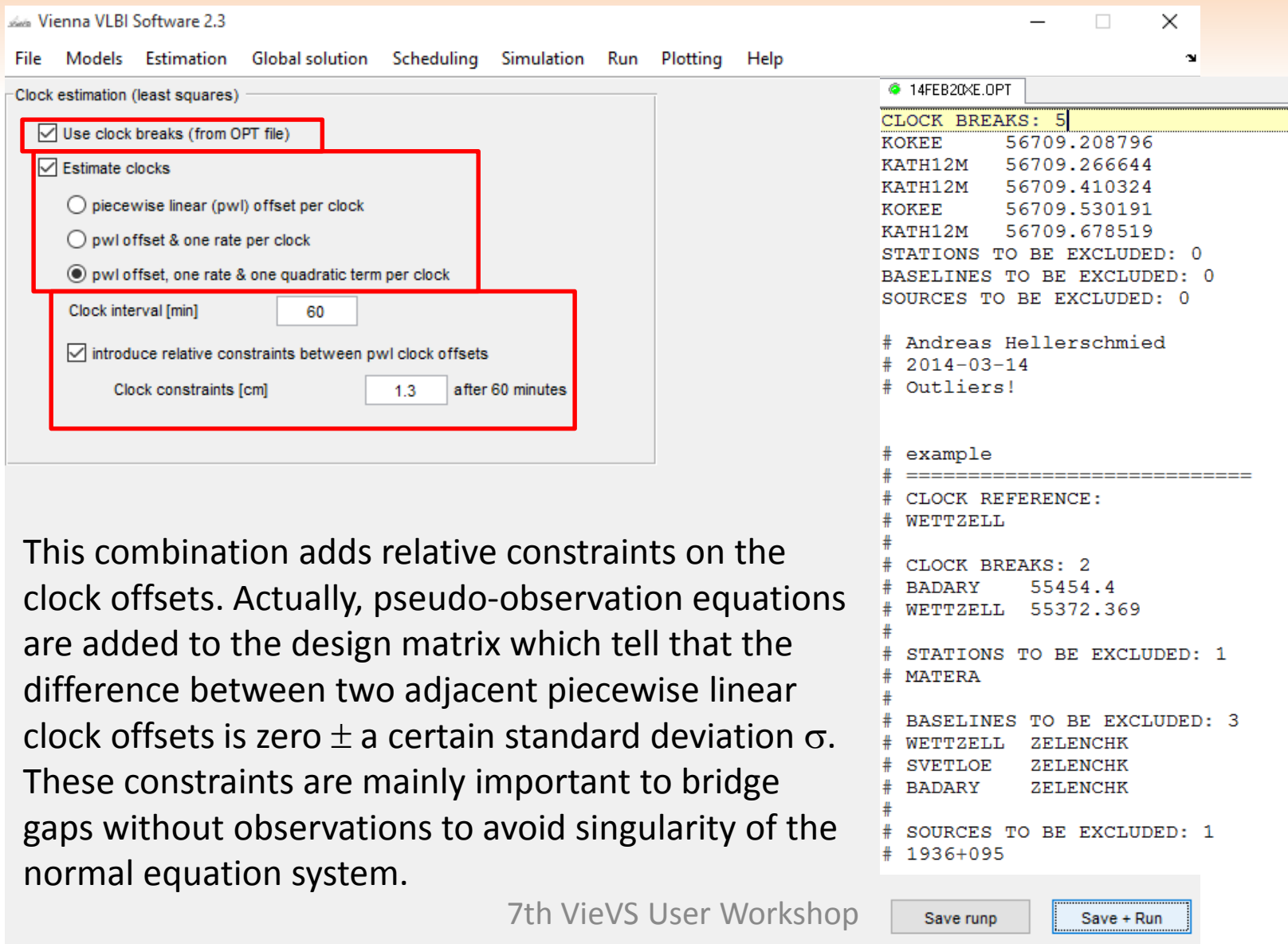
Outlier directory Eliminate outliers

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Save runp Save + Run

Clocks

(Coefficients of a quadratic function and PWLO)



The screenshot shows the Vienna VLBI Software 2.3 interface. The 'Clock estimation (least squares)' panel is active, with several options checked and highlighted by red boxes:

- Use clock breaks (from OPT file)
- Estimate clocks
 - piecewise linear (pwl) offset per clock
 - pwl offset & one rate per clock
 - pwl offset, one rate & one quadratic term per clock
- Clock interval [min]: 60
- introduce relative constraints between pwl clock offsets
 - Clock constraints [cm]: 1.3 after 60 minutes

The terminal window on the right shows the output for the '14FEB20XE.OPT' file:

```
CLOCK BREAKS: 5
ROKKEE      56709.208796
KATH12M     56709.266644
KATH12M     56709.410324
ROKKEE      56709.530191
KATH12M     56709.678519
STATIONS TO BE EXCLUDED: 0
BASELINES TO BE EXCLUDED: 0
SOURCES TO BE EXCLUDED: 0

# Andreas Hellerschmied
# 2014-03-14
# Outliers!

# example
# =====
# CLOCK REFERENCE:
# WETTZELL
#
# CLOCK BREAKS: 2
# BADARY     55454.4
# WETTZELL   55372.369
#
# STATIONS TO BE EXCLUDED: 1
# MATERA
#
# BASELINES TO BE EXCLUDED: 3
# WETTZELL   ZELENCHK
# SVETLOE    ZELENCHK
# BADARY     ZELENCHK
#
# SOURCES TO BE EXCLUDED: 1
# 1936+095
```

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.

Troposphere delays

(Zenith wet delays, north and east gradients)

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Troposphere estimation (least squares)

Zenith wet delays

- Estimate zenith wet delays
- ZWD interval [min]
- introduce relative constraints between pwl zenith wet delay offsets
- ZWD constraints [cm] after 60 minutes

Gradients

- Estimate north gradients
- NGR interval [min]
- introduce relative constraints between pwl NGR offsets
- NGR constraints [cm] after 360 minutes
- introduce absolute constraints between pwl NGR offsets
- NGR abs. constr. [cm]
- Estimate east gradients
- EGR interval [min]
- introduce relative constraints between pwl EGR offsets
- EGR constraints [cm] after 360 minutes
- introduce absolute constraints between pwl EGR offsets
- EGR abs. constr. [cm]

reduced from observations a priori to the adjustment

estimated

$$\Delta L(\alpha, e) = ZHDm_h(e) + ZWDm_w(e) + m_g(e)[G_n \cos(\alpha) + G_e \sin(\alpha)]$$

estimated

estimated

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Earth Orientation Parameters

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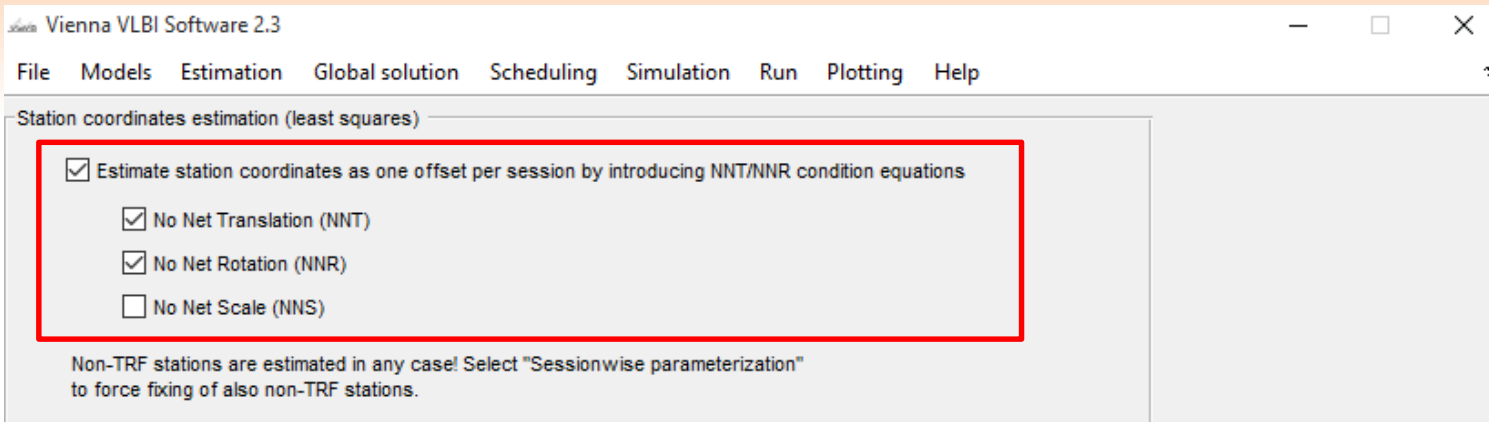
EOP estimation (least squares)

	estimation interval [min]	relative		
<input checked="" type="checkbox"/> Estimate Xpol (inter. pole coor. in TRF)	1440	<input checked="" type="checkbox"/> constraints [mas]	1.0e-4	after 1440 minutes
<input checked="" type="checkbox"/> Estimate Ypol (inter. pole coor. in TRF)	1440	<input checked="" type="checkbox"/> constraints [mas]	1.0e-4	after 1440 minutes
<input checked="" type="checkbox"/> Estimate dUT1 (rotation angle)	1440	<input checked="" type="checkbox"/> constraints [mas]	1.0e-4	after 1440 minutes
<input checked="" type="checkbox"/> Estimate nutdx (CIP coor. in celes. long.)	1440	<input checked="" type="checkbox"/> constraints [mas]	1.0e-4	after 1440 minutes
<input checked="" type="checkbox"/> Estimate nutdy (CIP coor. in obliquity)	1440	<input checked="" type="checkbox"/> constraints [mas]	1.0e-4	after 1440 minutes

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.

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

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Source estimation (least squares)

estimation interval [min]

Estimate source coordinates as pwl offsets 1440 relative constraints [mas] 1.0e-4 after 1440 minutes

Only non-CRF sources are estimated if this checkbox is ticked (select "Sessionwise parameterization" if you want otherwise...)

Estimate coordinates of all sources with NNR condition
(only sources in the catalogue are included in the NNR condition)

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vie_lsm scan-wise update

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Run options

VieVS modules

- Run vie_sched
- Run vie_init
- Run vie_mod
- Run vie_sim
- Run vie_lsm
- Run vie_glob

Sub-directory for (intermediate) results:
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Advanced options

- Use parallel processing Number of cores: auto Info: Faster for >1 sessions, but Command Window output is disarranged!
- Run vie_lsm scanwise update
- Use different sub-directories for (intermediate) output
 - /LEVEL0/...
 - /LEVEL1/...
 - /LEVEL2/...
 - /LEVEL3/...
- Stop process list if there is an error in a session

VIE_GLOB directory settings

N-matrices (LEVEL2) directory: ./DATA/LEVEL2/ Set default

Sub-directory: TEST_LEVEL2

Output directory for VIE_GLOB: TEST_OUT

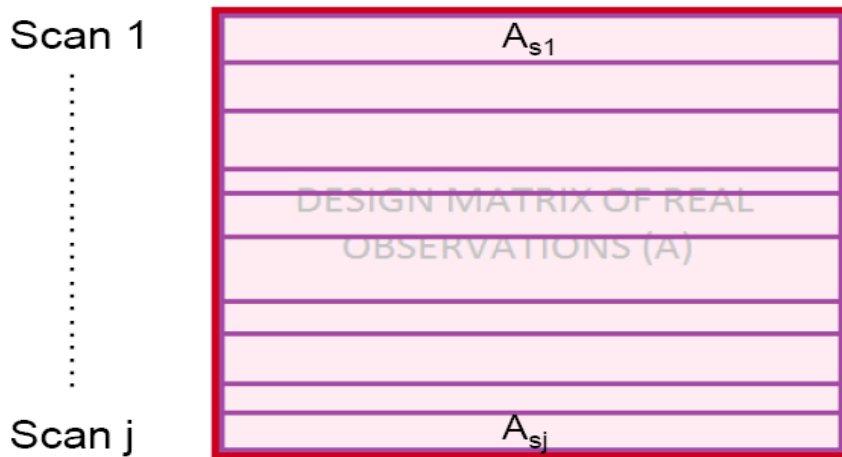
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Save runp Save + Run

For the VLBI sessions of which size of the design matrix and observation weight matrix is too large (consists too many observations) memory error occurred in Matlab. In order to get rid of this problem **vie_lsm scanwise update** should be selected!

Scan-wise update of normal equation system

1 A-matrix per scan



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

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

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

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

j : number of scans in the session

Conclusions

vie_lsm:

- corrects clock breaks and detects outlier observations.
- estimates geodetic parameters from VLBI 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.

Vie_LSM V2.3 - basics

Thanks for your attention!