

### Vie\_LSM V2.2 (part 1: 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 <u>piece-wise linear</u> <u>offsets (PWLO) in sub-daily and daily temporal resolution.</u>

### Estimated parameters per session are:

- Clocks (offset (cm), rate (cm/day), quadratic term (cm/day<sup>2</sup>), 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.

### **CPWLO** function



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



### Least-Squares Adjustment in vie\_lsm\_v22

$$A = \begin{bmatrix} A(1).sm & \cdots & A(15).sm \end{bmatrix} \longrightarrow \begin{array}{c} \text{design matrix of real observation} \\ \text{equations} \\ H = \begin{bmatrix} H(1).sm & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & H(15).sm \end{bmatrix} \bigoplus \begin{array}{c} \text{design matrix of pseudo-observation} \\ \text{equations (constraints)} \\ N = \begin{bmatrix} A^T PA + H^T P_H H & C^T \\ C & 0 \end{bmatrix} b = \begin{bmatrix} A^T Poc + H^T P_H och \\ b_c \end{bmatrix} \begin{array}{c} bc \text{ is a zero} \\ \text{vector} \\ (\text{due to NNT} \\ \text{and NNR} \\ \text{conditions} \end{array}$$

$$parameter \text{ vector} \\ (\text{estimates}) \\ x = N^- b \qquad m_0 = (v^T Pv + v_H^T P_H v_H) / (n_{obs} + n_{constr} - n_{unk}) \\ K_x = m_0 N^- \qquad \text{variance-covariance matrix of the} \\ estimates \end{bmatrix}$$

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



# Parameterisation of Least-Squares Adjustment in VieVS

Vienna VLBI Soft	ware 2.2	and the second sec	
File Parameters	Estimation Global solution	n Scheduling Simulation Run Plotting Help	لار ا
File Parameters Set input files Process list 2002/02OCT162 OPT file OPT directory Outlier file Outlier directory	Estimation Global solution	Scheduling Simulation Run Plotting Help   Troposphere   Clock EOP   Station coordinates   Source coordinates   Add previous   Clear selected	
		6th VieVS User Workshop Save runp	Save + Run

#### Clocks

### (Coefficients of a quadratic function and PWLO)

Jaan Vienna VLBI Software 2.2	
File Parameters Estimation Global solution Scheduling Simulation Run Plotting Help	لا
Clock estimation (least squares)	14FEB20XE.OPT
Use clock breaks (from OPT file)	CLOCK BREAKS:         5           KOKEE         56709.208796           KATH12M         56709.266644
piecewise linear (pwl) offset per clock	KATH12M 56709.410324 KOKEE 56709.530191
	KATH12M 56709.678519
	STATIONS TO BE EXCLUDED: 0
pwl offset, one rate & one quadratic term per clock	BASELINES TO BE EXCLUDED: 0
Clock interval [min] 60	SOURCES TO BE EXCLOSED. 0
✓ introduce relative constraints between pwl clock offsets	# Andreas Hellerschmied
Clock constraints [cm] 13 after 60 minutes	# 2014-03-14 # Outliers!
	" Outlield.
	# example # ====================================
	# CLOCK REFERENCE: # WETTZELL
This combination adds relative constraints on the	# # CLOCK BREAKS: 2
clock offsets. Actually, pseudo-observation equations	# BADARY 55454.4
	# WETTZELL 55372.369 #
are added to the design matrix which tell that the	# STATIONS TO BE EXCLUDED: 1
difference between two adjacent piecewise linear	# MATERA
alack offects is zero. La contain standard doviation -	# BASELINES TO BE EXCLUDED: 3
CIOCK OTSELS IS ZERO $\pm$ a Certain standard deviation o.	# WETTZELL ZELENCHK
These constraints are mainly important to bridge	# BADARY ZELENCHK
gans without observations to avoid singularity of the	# # SOURCES TO BE EXCLUDED: 1
Bups without observations to avoid singularity of the	# 1936+095
normal equation system.	
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# Tropopshere delays (Zenith wet delays, north and east gradients)

Vienna VLBI Software 2.2	
File         Parameters         Estimation         Global solution         Scheduling         Simulation         Run         Plotting         Help         Number of the second se	
Troposphere estimation (least squares)	
Zenth wet delays         WD interval [min]       60         Introduce relative constraints between pwl zenth wet delay offsets         ZWD constraints [cm]       1.5         Gradients         Gradients         Introduce relative constraints between pwl NGR offsets         NGR interval [min]       360         Introduce relative constraints between pwl NGR offsets         NGR constraints [cm]       0.05         Introduce absolute constraints between pwl NGR offsets         NGR constraints [cm]       0.05         Introduce absolute constraints between pwl NGR offsets         NGR interval [min]       360         Introduce relative constraints between pwl NGR offsets         NGR interval [min]       360         Estimate east gradients         EGR interval [min]       360         Introduce absolute constraints between pwl EGR offsets         EGR interval [min]       360         Introduce absolute constraints between pwl EGR offsets         EGR interval [min]       360         Introduce absolute constraints between pwl EGR offsets         EGR interval [min]       0.05         EGR interval [min]       0.1	estimated + $ZWD m_w(\varepsilon)$ + $G_e \sin(\alpha)$ ] estimated
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### **Earth Orientation Parameters**

sin V	ienna VLBI Software 2.2		Constant of			x			
File	Parameters Estimation Global solution Sch	eduling Sim	ulation Run Plotting	Help		r			
— EO	EOP estimation (least squares)								
	es	stimation interval	l [min] relative						
	✓ Estimate Xpol (inter. pole coor. in TRF)	1440	constraints [mas]	1.0e-4	after 1440 minutes				
	Stimate Ypol (inter. pole coor. in TRF)	1440	✓ constraints [mas]	1.0e-4	after 1440 minutes				
	✓ Estimate dUT1 (rotation angle)	1440	constraints [mas]	1.0e-4	after 1440 minutes				
	Stimate nutdx (CIP coor. in celes. long.)	1440	constraints [mas]	1.0e-4	after 1440 minutes				
	Stimate nutdy (CIP coor. in obliquity)	1440	✓ 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.

Save runp

### Antenna TRF coordinates

wa Vienna VLBI Software 2.2								
File Parameters Estimation Global solution Scheduling Simulation Run Plotting Help	لا							
- Station coordinates estimation (least squares)								
<ul> <li>Estimate station coordinates as one offset per session by introducing NNT/NNR condition equations</li> <li>No Net Translation (NNT)</li> <li>No Net Rotation (NNR)</li> <li>No Net Scale (NNS)</li> </ul>								
Non-TRF stations are estimated in any case! Select "Sessionwise parameterization" to force fixing of also non-TRF stations.								
<ul> <li>NNT and NNR conditions are imposed to provide the estimated</li> </ul>								

- 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.

Save + Run

### Source CRF coordinates

🚧 Vienna VLBI So	ftware 2.2					(reality)				
File Parameters	Estimation	Global solution	Scheduling	Simulation	Run	Plotting I	Help			Ľ
- Source estimation (least squares)										
V Estimate s	ource coordinate	es as pwl offsets	esumation 1	440	relativ	e constraints	[mas]	1.0e-4	after 1440 r	ninutes
Only non-O if you war	RF sources are t otherwise)	estimated if this cheo	ckbox is ticked (s	elect "Sessior	nwise par	rameterizatior	r.			
Estimate co	ordinates of all	sources with NNR co	ndition							
(only source	es in the catalog	gue are included in the	e NNR condition)							
			(	5th Vie	VS Us	ser Wo	rkshop	Save ru	np gr	Save + Run

### vie\_lsm scan-wise update

Sienna VLBI Software 2.2											
File	Parameters	Estimation	Global solution	Scheduling	Simulation	Run	Plotting	Help		Ľ	
- Run	options Scheduling										
	y										
						F	Run vie_sch	ed			
- 5	Simulation										
						<b>F</b>	Run vie_sim				
	/ieVS										
	• one subdire	ctory (recomme	nded)	forwork	shop						
	O different su	bdirectories /LEV/EL0/		/LEV/EL1/			/LEV/EL3/		For the VLBI	sessions of	f which size
	vie_init->		vie_mod ->		vie_ism	->			of the design	matrix an	d
					vie_glob	->	/LEVEL2/		observation	weight ma	trix is too
						<b>V</b> F	Run vie_init		large (consist	s too man	v
						<b>V</b> F	Run vie_mod		observations	) memory	error
			<b></b>	un vie_lsm scanv	vise update	<b>F</b>	Run vie_lsm		occured in m	atlah In o	rder to get
			[	Run parallel	Number of	i cores	auto 🔻		rid of this pro	hlom this	ontion
			l (	nfo: Faster for >' Command Windoy	l sessions, but v outout is dise	: amanged			chould be col	loctod	option
	Global solution								should be se	lecteu!	
	Path to LEVE	L2 data	/DATA/LEVE	.2/ Get de	fault						
	LEVEL2 subd	lirectory	TEST_LEVEL2								
	Output direct	ory for vie_glob	TEST_OUT			F	Run vie_glob				
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### 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

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

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### 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.

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### Thanks for your attention!