



# VIE\_LSM\_V20

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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>continuous piece-wise linear offsets</u> (CPWLO) in sub-daily and daily temporal resolution.





## Estimated parameters are:

- Clocks (offset (cm), rate (cm/day), quadratic term (cm/day<sup>2</sup>), CPWLO (cm)),
- E Zenith wet delays (cm) as CPWLO,
- Troposphere gradients (cm) as CPWLO,
- ► EOP (mas and ms) as CPWLO,
- Antenna coordinates in TRF (cm) as one offset per session or as CPWLO,
- Source coordinates in CRF (mas) as CPWLO.





# <u>continuous piece-wise linear offsets</u> (CPWLO)



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# Partial derivatives of the delay model w.r.t. a sub-daily parameter



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





$$A = \begin{bmatrix} A(1).sm & \cdots & A(15).sm \end{bmatrix} \bigoplus \text{ design matrix of real observation} \\ \text{equations} \\ H = \begin{bmatrix} H(1).sm & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & H(15).sm \end{bmatrix} \bigoplus \text{ design matrix of pseudo-observation} \\ \text{equations (constraints)} \\ N = \begin{bmatrix} A^T PA + H^T P_H H & C^T \\ C & 0 \end{bmatrix} b = \begin{bmatrix} A^T Poc + H^T P_H och \\ b_c \end{bmatrix} b^{c} \text{ is a zero vector} \\ \text{(due to NNT and NNR conditions} \\ \text{parameter vector} \\ \text{(estimates)} \\ x = N^- b \qquad m_0 = (v^T Pv + v_H^T P_H v_H) / (n_{obs} + n_{constr} - n_{unk}) \\ K_x = m_0 N^- \bigoplus \text{ variance-covariance matrix of the} \\ \text{estimates} \end{bmatrix}$$





### Modeling clock breaks







Jame Vienna VLBI Software 2.0	
File Parameters Estimation Global solution Simulation	Scheduling Run Plotting Help 🏻 🍟
Set input files  Process list  Kalman filter  Clock  EOP  Station coordi Source coordi  Add previou  Clear selecte  OPT file  OPT directory VIENNA  Cutlier file  Outlier file  Outlier file  CONT11  Eliminate outliers	hates hates
	Save runp Save + Run









Vienna VLBI Software 2.0	
le Parameters Estimation Global solution Simulation Scheduling Run Plotting Help	¥
Clock estimation (least squares)	
Use clock breaks (from OPT file)	
Estimate clocks	
piecewise linear (pwl) offset per clock	
pwl offset & one rate per clock	
ø pwl offset, one rate & one quadratic term per clock	
Clock interval [min] 30	
introduce relative constraints between pwl clock offsets	
Clock constraints [ps^2/s] 0.5	
Save	runp Save + Run





#### 🚧 Vienna VLBI Software 2.0

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le Parameters Estimation Global solution Simu	ulation Schedu	ling Run Plotting Help								
OP estimation (least squares)										
est	imation interval [mir	n]								
Estimate Xpol (inter. pole coor. in TRF)	60	🔽 constraints [mas/day]	30							
Estimate Ypol (inter. pole coor. in TRF)	60	Constraints [mas/day]	30							
Estimate dUT1 (rotation angle)	30	constraints [ms/day]	2							
Estimate nutdx (CIP coor. in celes. long.)	1440	✓ constraints [mas/day]	0.0001							
Estimate nutdy (CIP coor. in obliquity)	1440	✓ constraints [mas/day]	0.0001							

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Save + Run

Save runp





sinta V	ienna VLBI Soft	tware 2.0								
File	Parameters	Estimation	Global solution	Simulation	Scheduling	Run	Plotting	Help		¥.
- Sta	ation coordinates	estimation (leas	st squares)———							
	V Estimate sta	ition coordinate	s as one offset per s	session by intro	ducing NNT/NN	R condi	tion equation	s		
	Vo No	et Translation (N	INT)							
	📝 No Ne	et Rotation (NNF	ÿ							
	No No	et Scale (NNS)								
I										
									Save runp	Save + Run





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File	Parameters	Estimation	Global solution	Simulation	Scheduling	Run	Plotting	Help		צי
- So	urce estimation (	least squares)-								
	🔽 Estimate so	urce coordinate	e se nwl offeste	estimati	on interval [min]		strainte Imae	/davl	0.0001	
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	if you want	otherwise)	estaimted if this che	CKDOX IS LICKED	(select Sessio	nwise p	arameteriza	tion		
									Save runp	Save + Run





Jaan Vienna VLBI Software 2.0	
File Parameters Estimation Global solution Simulation Scheduling Run Plotting Help	Ľ
VieVS processing settings First solution VieVS processing settings Vi	
<ul> <li>one offset per clock</li> <li>one offset &amp; one rate per clock</li> <li>one offset one rate &amp; one quadratic term per clock</li> </ul>	
Manually find clock breaks	
Imain solution         Imain	
Estimate parameters (otherwise: only N matrix created)     Write all parameters to ASCII file Save as     Allow for stationwise and sourcewise parameterization for each session	
Save runp	Save + Run





## **Clocks for first solution**

vie_lsm [	ingle session first solution ]	
parameterization for removing large clock errors		
apply first basic solution (only with clock function)	apply main solution	
○ one offset per clock		coefficient
one offset & one rate per clock	simple outlier test [ coefficient	t * mo ] 5
	basic outlier test [ coefficient <sup>4</sup>	* mo *sqrt(qvv) ]
one onset, one rate, & one quadratic term per clot		
✓ use clock breaks (From OPT file)	clock/s that have breaks in the ses	sion
- reference clock for the first so	No clock breaks information!	
WETTZELL		
FORTLEZA		Next
WESTFORD		
BADARY VERES40M		
WETTZELL		
TSUKUB32		
HARTRAO		
HOBART12		
KOKEE		
ONSALA60		
TIGOCONC		
ZELENCHK		





### Clocks

vie_lsm_gui_clock					
		-:			
	e ses	SION CIOCI	ks j		
parameterization for clocks	[		clock constraints clock	interval ref	ference clock
		FORTLEZA	0.5000	30	
✓ estimate clocks		WESTFORD	0.5000	30	
ningenuise lineer (nul) offerte per cleak		BADARY	0.5000	30	
O precewise inear (pwi) onsets per clock		YEBES40M	0.5000	30	
○ pwl offsets & one rate per clock		WETTZELL	0.5000	30	
		TSUKUB32	0.5000	30	
• pwl offsets, one rate, & one quadratic term per clock			0.5000	30	
		HOBARTIZ	0.5000	30	
introduce relative constraints between pwl clock offsets		ONSAL A60	0.5000	30	
		TIGOCONC	0.5000	30	
- Default reference clock has not any clock break.		ZELENCHK	0.5000	30	
<ul> <li>Reference clock is the first clock in the NGS file</li> <li>OR if any OPT file of the session exists fixed clock is from OPT file</li> <li>Unit of clock estimation intervals is minutes.</li> <li>Unit of clock constraints is picosec<sup>A</sup>2/sec</li> </ul>					
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### Troposphere delay

📣 vie_lsm_gui_tro	ро												
				vie_lsm [	single s	ession t	ropos	phe	ere ]				
apply relati	apply relative constraints between tropospheric offset estimates												
introduce REI	ATIVE CONSTR	AINTS between	pwi ZENITH WE	T DELAY offsets				- unit (	of ZWD relativ	ve constraint	s is picosec^2/se	c e.g. 0.7 pico:	sec^2/sec
introduce REA	ALTIVE CONSTR	AINTS between	nwittene NOR		isets			relativ	ely loose.				
					5015			- unit ( relativ	of NGR & EGR ely loose.	relative con	straints is millimete	er/day e.g. 2 m	m/day
introduce REI	LATIVE CONSTR	AINTS between	n pwl tropo. EAS	T GRADIENT offs	ets			- unit (	of NGR & EGR	absolute co	nstraints is millime	tere.a. 1 mm a	absolutely
introduce AB	SOLUTE CONST	RAINTS betwee	n pwl tropo. NO	RTH GRADIENT of	ffsets			loose.					
introduce AB	SOLUTE CONST	RAINTS betwee	en pwi tropo. EAS	ST GRADIENT offs	sets								
	ZWD coef.	NGR rel. coef.	EGR rel. coef.	NGR abs. coef. E	GR abs. coef.	ZWD int.	NGR int		EGR int.	est. ZWD	est. NGR	est. EGR	
FORTLEZA	0.7000	2	2	1	1	30	1	180	180				<u>_</u>
WESTFORD	0.7000	2	2	1	1	30	1	180	180				
BADARY	0.7000	2	2	1	1	30		180	180	V		V	-
WETTZELL	0.7000	2	2	1	1	30		180	180			V	=
TSUKUB32	0.7000	2	2	1	1	30		180	180				
HARTRAO	0.7000	2	2	1	1	30		180	180				
HOBART12	0.7000	2	2	1	1	30	1	180	180	<b>V</b>			
KOKEE	0.7000	2	2	1	1	30		180	180	<b>V</b>		<b>V</b>	-
1													
											Back		Next





### TRF antenna coordinates

vie_lsm_gui_statcoor											
vie_Ism [ single session station coordinates ]											
- general options for estimation of stations coordinates-	1	NNT	NNR	NNS	XYZ_est	constraints	coor. intervals				
	FORTLEZA		<b>V</b>		<b>V</b>	100	360				
estimate station coordinates	WESTFORD	<b>V</b>	<b>V</b>			100	360				
	BADARY		<b>V</b>		<b>V</b>	100	360				
one offset per session	YEBES40M					100	360				
	WETTZELL		<b>V</b>		<b>V</b>	100	360				
NNT/NNR	TSUKUB32				V	100	360				
	HARTRAO		<b>V</b>		<b>V</b>	100	360				
<ul> <li>Fix some stations</li> </ul>	HOBART12					100	360				
	KOKEE					100	360				
pwl offsets per session	ONSALA60	<b>V</b>	<b>V</b>			100	360				
	TIGOCONC					100	360				
	ZELENCHK	<b>V</b>	<b>V</b>		<b>V</b>	100	360				
						Back	Next				





### TRF antenna coordinates

vie_lsm_gui_statcoor					-		- 0 <mark>- X</mark>				
vie_Ism [ single session station coordinates ]											
-general options for estimation of stations coordinates		NNT	NNR	NNS	XYZ_est	constraints	coor. interva				
	FORTLEZA					100	36				
✓ estimate station coordinates	WESTFORD					100	36				
	BADARY					100	36				
one offset per session	YEBES40M				$\checkmark$	0.0100	144				
	WETTZELL					100	36				
	TSUKUB32					0.0100	144				
	HARTRAO					100	36				
	HOBART12					0.0100	144				
	KOKEE					2400	6				
øwl offsets per session	ONSALA60					100	36				
	TIGOCONC				<b>V</b>	0.0100	144				
Fix some stations	ZELENCHK					100	360				
☑ introduce relative constraints between pwl coordinate offsets		•									
					Back	k 📃	Next				





### EOP

arth Orientation Parameter (EOP) pwl offsets e	estimation options	;			
	include model e	stimation interval us	e constraints	constraints	
Xpol (inter. pole coor. in TRF )		60		30	
Ypol (inter. pole coor. in TRF )		60		30	
dUT1 (rotation angle)		60		2	
nutdx (CIP coor. in celes. long.)		1440		1.0000e-04	
nutdy (CIP coor. in obliquity)		1440		1.0000e-04	





### **CRF** source coordinates

vie_lsm_gui_sourcoor							
vie_lsm [ sing	e se	ssion so	urce coord	inates ]			
estimate coordinates of sources as pwl offsets [	all the	unselected	sources will be	e fixed to C	RF ]		
introduce relative constraints between pw	lo sou	irce coordir	nates				
<ul> <li>unit of constraints is mas/day.</li> <li>unit of coordinate estimation intervals in minutes.</li> <li>Please, fix at least one source which has more than 1 observation if you select estimate sources</li> </ul>	82	source name 1520+437	total observations 18	est. coor.	constraints 1.0000e-04	coor. interval 1440	
	83	2309+454	7		1.0000e-04	1440	
	84	0506-612	1		1.0000e-04	1440	
	85	0134+311	21		1.0000e-04	1440	
	80	1352-104	4		1.0000e-04	1440	
	87	2250+194	3		1.0000e-04	1440	
	89	0111+021	2		1.0000e-04	1440	
	90	1754+155	71		1.0000e-04	1440	
	91	2319+317	70		1.0000e-04	1440	-
						Back	Next



# Conclusions



- vie\_lsm corrects clock breaks and detects outlier observations.
- vie\_lsm provides SINEX input and datum free normal equations for global solutions (vie\_glob).
- CPWLO estimates of VieVS are in a good agreement with those derived from other space geodetic techniques.
- Tidal motions of the antenna TRF positions on sub-daily resolution (<u>e.g. 1 hour during CONT11</u>) can be unveiled accurately with VieVS.



CONT11





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### Fourier spectra of the hourly Kokee TRF coordinates









# Thank you so much for your attention!