Different Tropospheric Mapping Functions and Cut off Angles Investigated by Processing VLBI CONT05 Sessions

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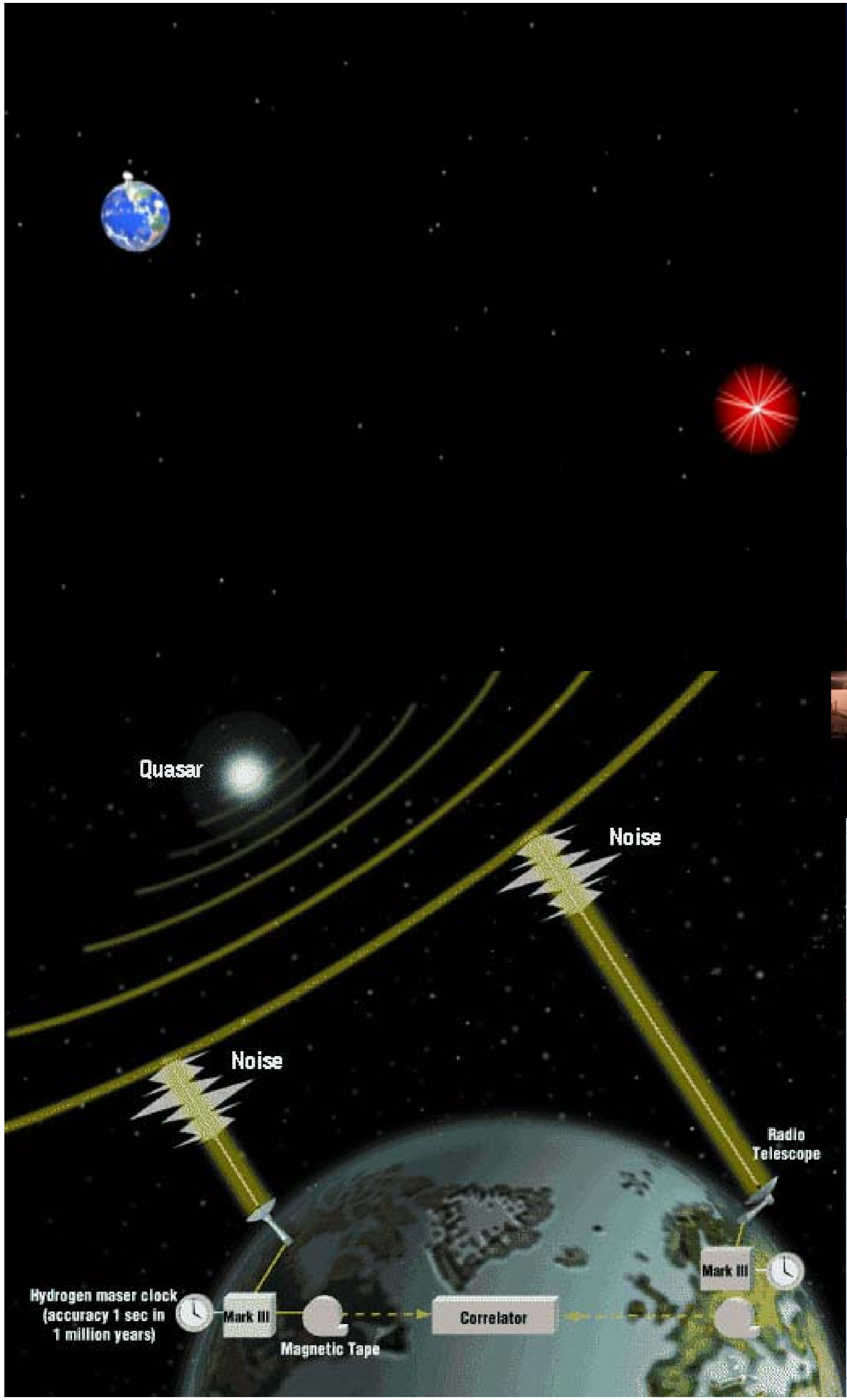
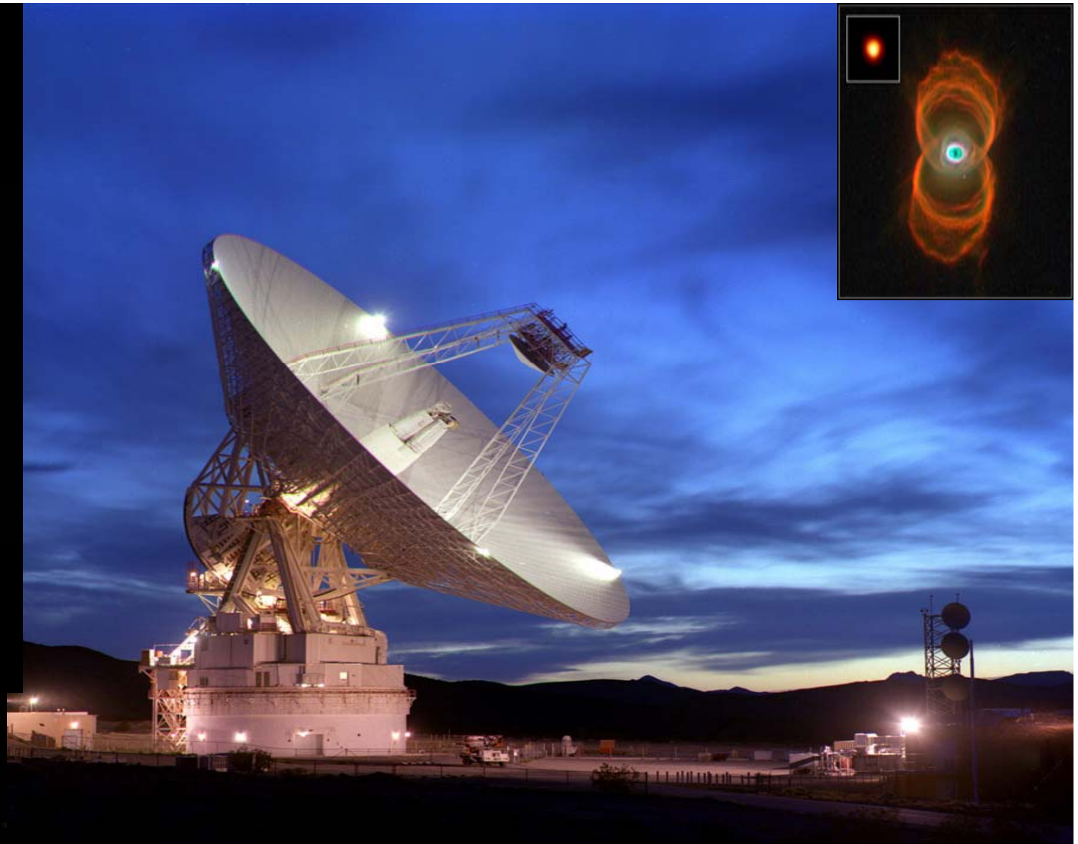
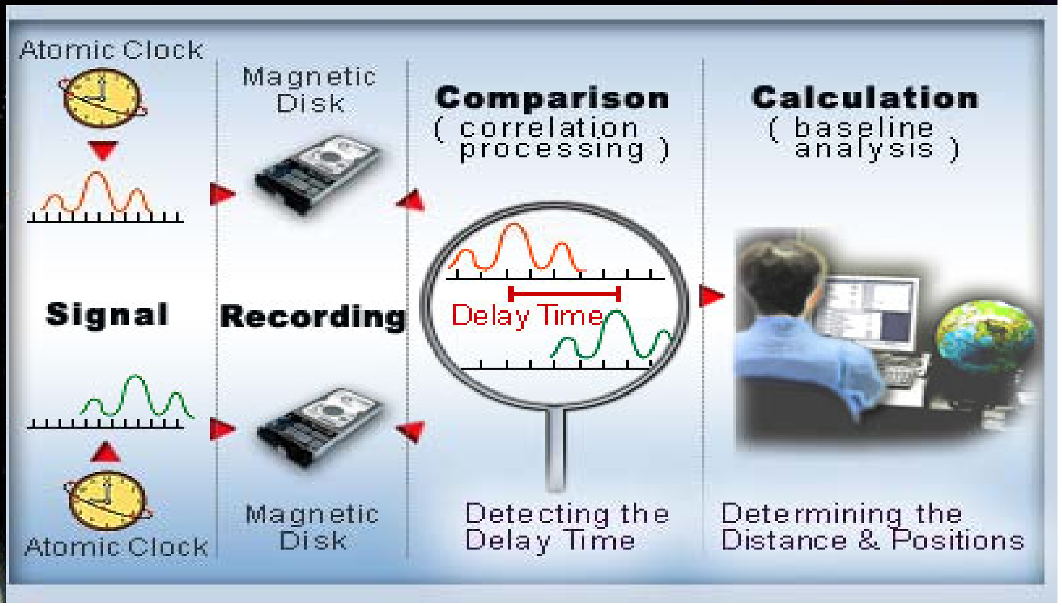

Quasar
Noise
Noise
Radio Telescope
Mark III
Hydrogen maser clock (accuracy 1 sec in 1 million years)
Mark III
Magnetic Tape
Correlator




Atomic Clock
Signal
Atomic Clock
Magnetic Disk
Recording
Magnetic Disk
Comparison
(correlation processing)
Delay Time
Detecting the Delay Time
Calculation
(baseline analysis)
Determining the Distance & Positions

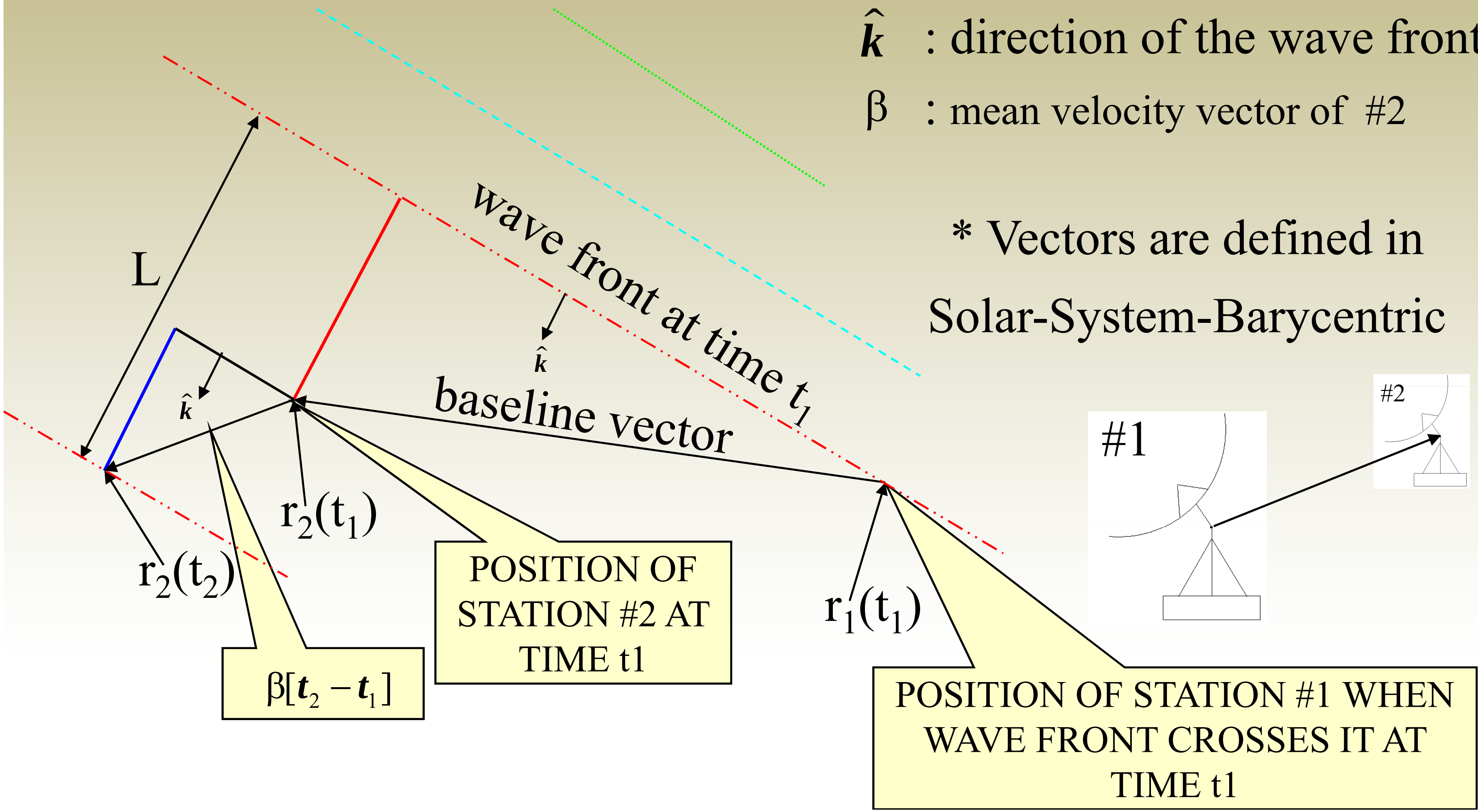
VLBI GEOMETRIC MODEL

$$c(\tau_{obs}-(\tau_{clock}+\tau_{trop}+\tau_{ionos}+\tau_{rel})) = c.(t_2-t_1) = \hat{\boldsymbol{k}}\,[r_2(t_1)-r_1(t_1)] + \hat{\boldsymbol{k}}\,\beta\,[t_2-t_1]$$

$\hat{\boldsymbol{k}}$: direction of the wave front

β : mean velocity vector of #2

* Vectors are defined in Solar-System-Barycentric



VLBI TROPOSPHERE MODEL

Total Delay = Ionospheric Delay + Neutral Delay

Zenith Neutral Delay = Zenith Hydrostatic Delay + Zenith Wet Delay

$$\Delta L(e) = ZHD.mf_h(e) + ZWD.mf_w(e)$$

$\Delta L(e)$: Zenith neutral path delay

$mf_{h,w}$: Hydrostatic, wet tropospheric mapping functions (NMF, GMF, IMF, VMF1)

$ZHD = f(\varphi, H, P)$: Zenith Hydrostatic delay

ZWD = Estimated in VLBI analysis by piecewise linear function : Zenith wet delay

$$\tau_{troposphere} = -\frac{1}{c}(\Delta L_2(e) - \Delta L_1(e)) \qquad \text{(for the station 1 and 2)}$$

TROPOSPHERIC MAPPING FUNCTIONS

$$m_{h,w}(e) = \frac{1+\cfrac{a_i}{1+\cfrac{b_i}{1+\cfrac{c_i}{1+\cdots}}}}{\sin(e)+\cfrac{a_i}{\sin(e)+\cfrac{b_i}{\sin(e)+\cfrac{c_i}{\sin(e)+\cdots}}}}$$

e : Elevation cut off angle

$a_i, b_i, c_i, \cdots = f(\varphi, H, doy, t, \alpha, ...)$

φ : station latitude

H : station orthometric height

doy : day of year

P : surface total pressure

t : surface temperature

α : tempreature lapse rate

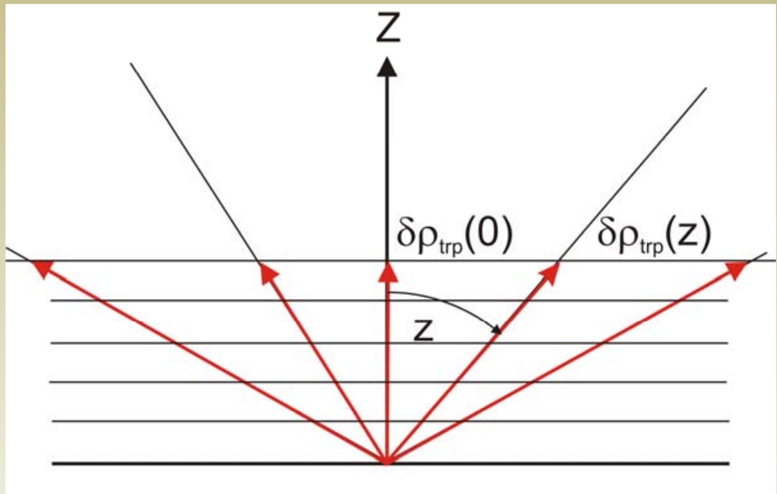
Niell Mapping Function

Isobaric Mapping Function

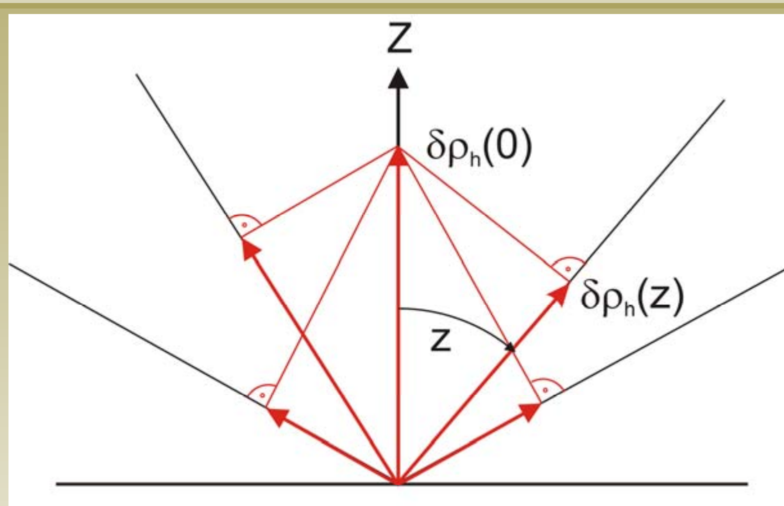
Vienna Mapping Function

<u>Some other mapping functions:</u>

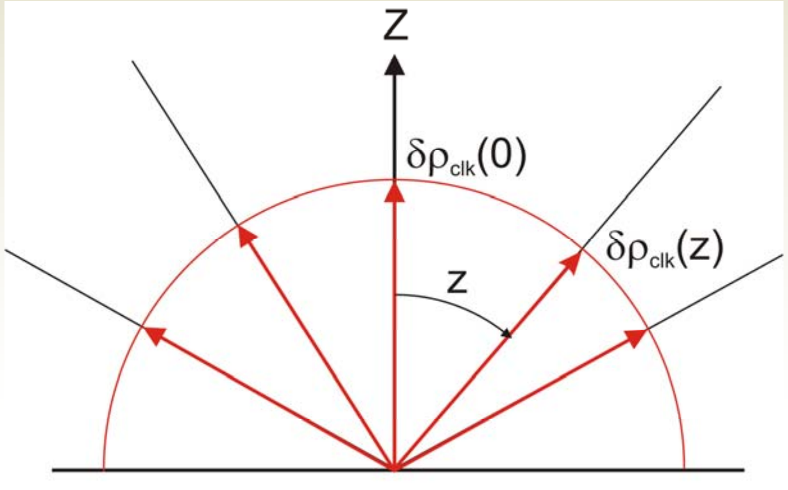
Chao, Ifadis, Davis, MTT, B&E, F&K, UNBabc, UNBab



$$\delta\rho_{trp}(z) = mf(z)\cdot\delta\rho_{trp}(0) \sim 1/\cos(z)\cdot\delta\rho_{trp}(0)$$



$$\delta\rho_{h}(z) = \cos(z)\cdot\delta\rho_{h}(0)\ ;\ \delta\rho_{h}(0)=\delta h$$



$$\delta\rho_{clk}(z) = \delta\rho_{clk}(0) = c\cdot\delta t_R$$

VLBI CONT05 STATIONS

CONT05 was a two-week campaign of continuous VLBI sessions, scheduled for observing during September 2005.

The plan for the CONT05 campaign is to acquire state of the art VLBI data over a two-week period to demonstrate the highest accuracy of which VLBI is capable.

Regression function of the baseline length repeatabilities and fitting a curve

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(L_i - L_0)^2}{n-2}}$$

→ Formal errors as baseline length repeatabilities

$$y = a^2 + b^2 ppb^2 L^2$$

→ Regression function for baseline length repeatabilities

LSM Application

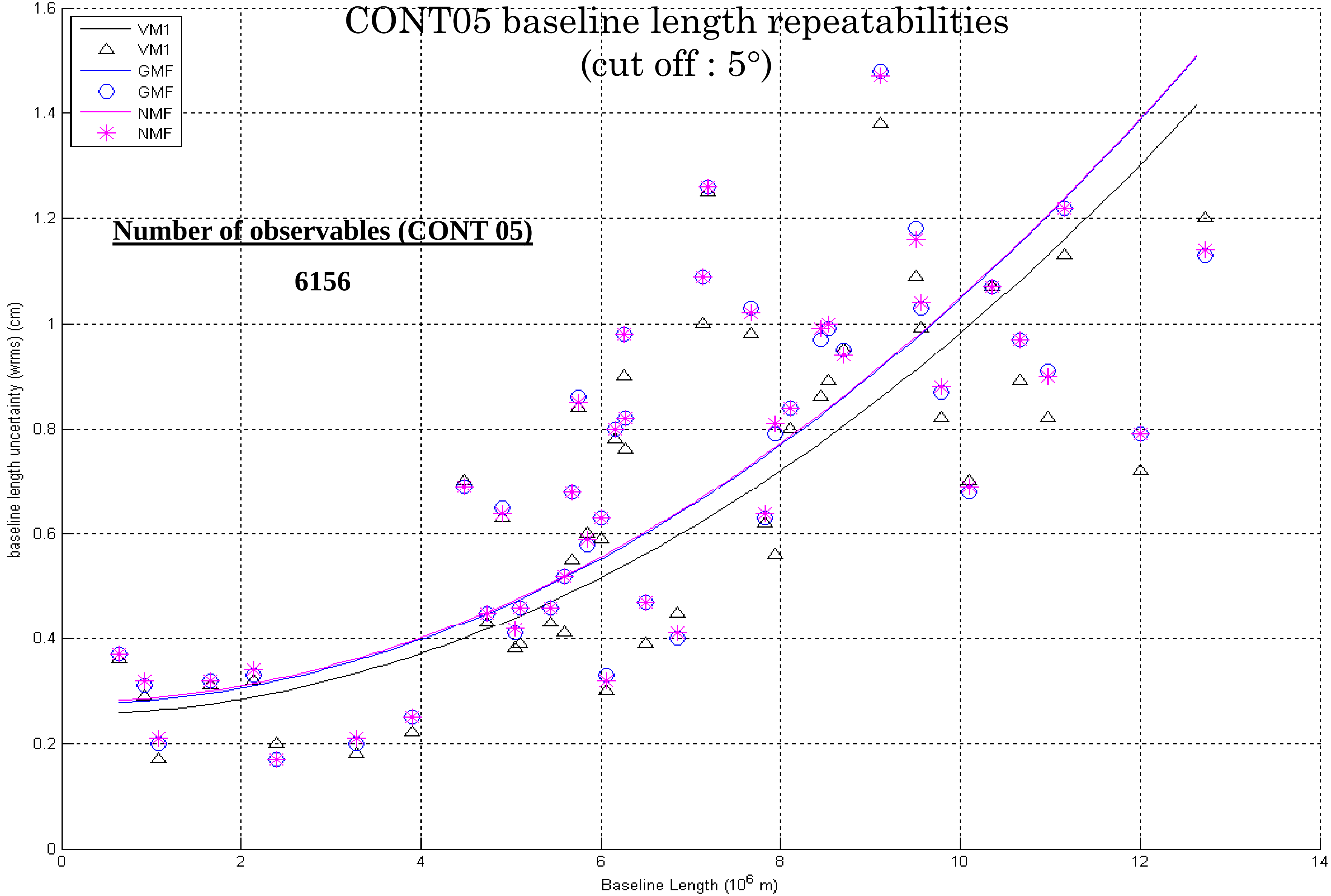
$$y = \begin{bmatrix} rms_1^2 \\ rms_2^2 \\ \vdots \\ rms_n^2 \end{bmatrix}; \quad A = \begin{bmatrix} 1 & ppb^2 L_1^2 \\ 1 & ppb^2 L_2^2 \\ \vdots & \vdots \\ 1 & ppb^2 L_n^2 \end{bmatrix}; \quad x = \begin{bmatrix} a^2 \\ b^2 \end{bmatrix}; \quad W = \begin{bmatrix} 1/s_1^2 & & & \\ & 1/s_2^2 & & \underline{0} \\ & & \ddots & \\ & \underline{0} & & \\ & & & 1/s_n^2 \end{bmatrix}$$

$$x = (A^T W A)^- A^T W \, y$$

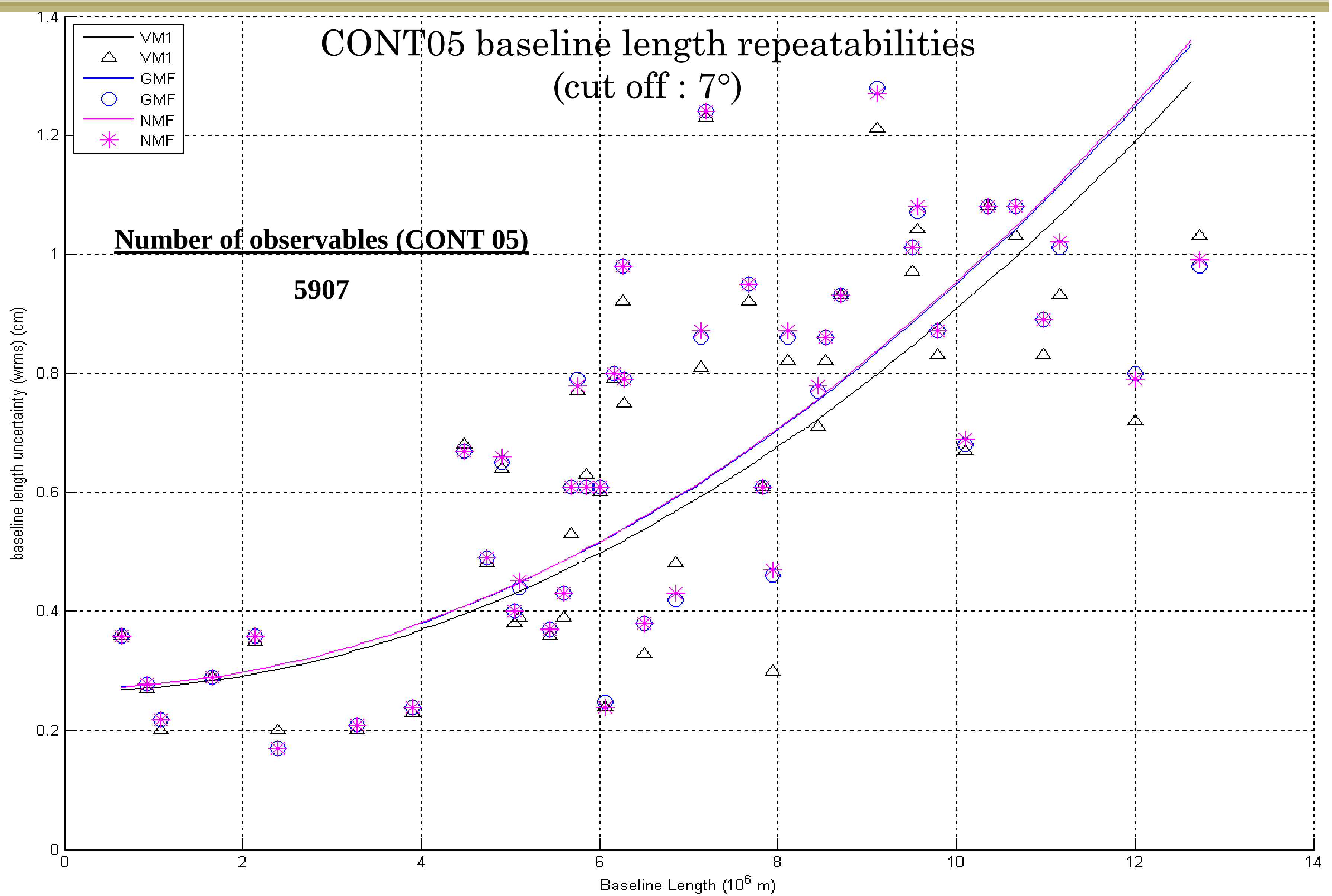
Values of the estimated parameters by LSM

Mapping Functions	Parameters of the function for different cut off angles									
	5° (6156)		6°(6028)		7°(5907)		8°(5818)		9°(5646)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VMI	0.505	0.853	0,515	0,817	0,517	0,801	0,523	0,796	0,510	0,836
GMF	0,524	0,879	0,521	0,844	0,521	0,823	0,522	0,806	0,512	0,844
NMF	0,528	0,879	0,520	0,844	0,521	0,826	0,522	0,808	0,512	0,845
Mapping Functions	10°(5502)		12°(5207)		15°(4730)		20°(3906)		30°(2491)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VMI	0,501	0,859	0,489	0,927	0,428	1,078	0,404	1,229	0,657	1,542
GMF	0,500	0,866	0,488	0,931	0,426	1,081	0,403	1,229	0,656	1,542
IMF	0,500	0,867	0,489	0,931	0,428	1,081	0,404	1,228	0,655	1,543

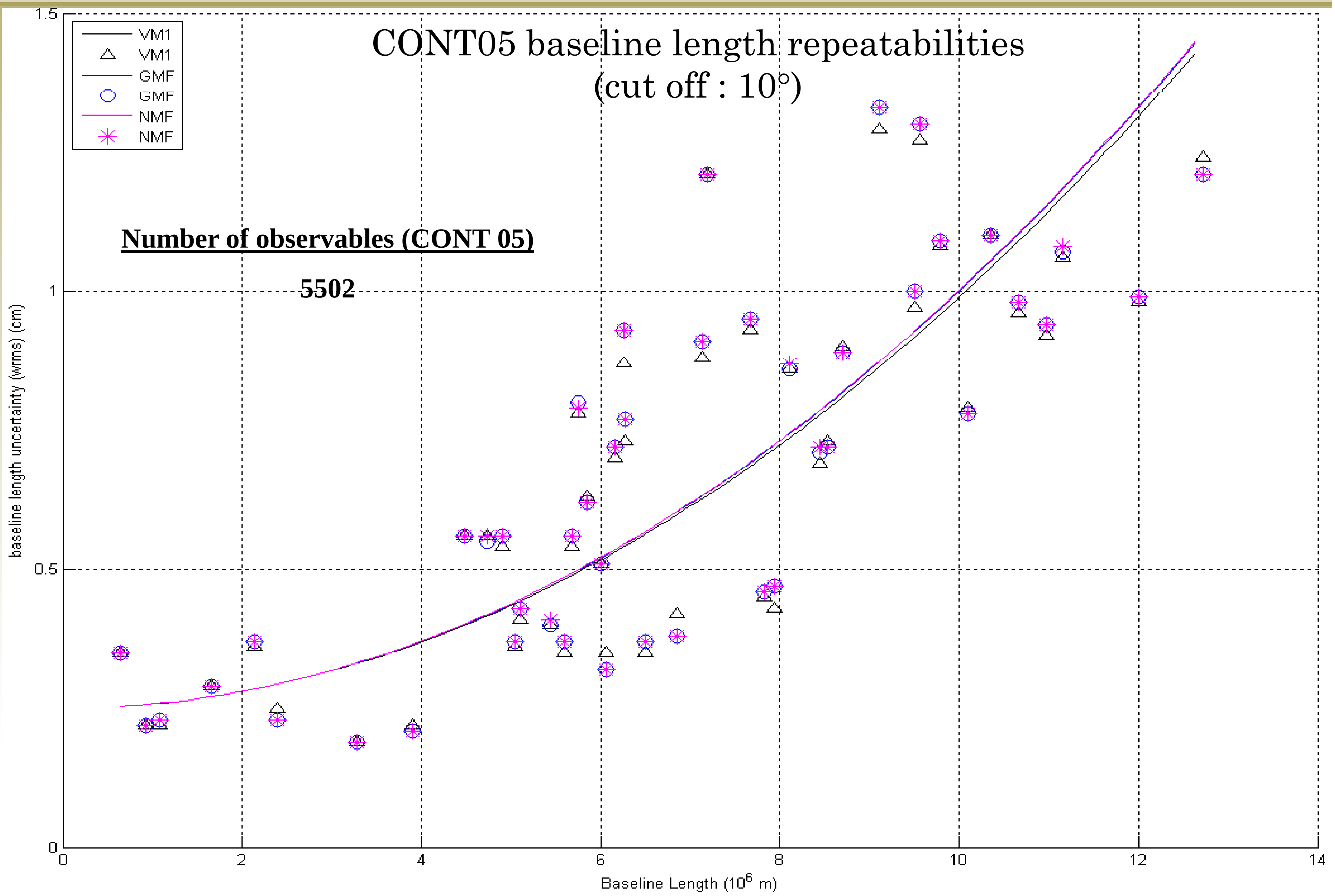
Different Tropospheric Mapping Functions and Cut off Angles Investigated by Processing VLBI CONT05 Sessions



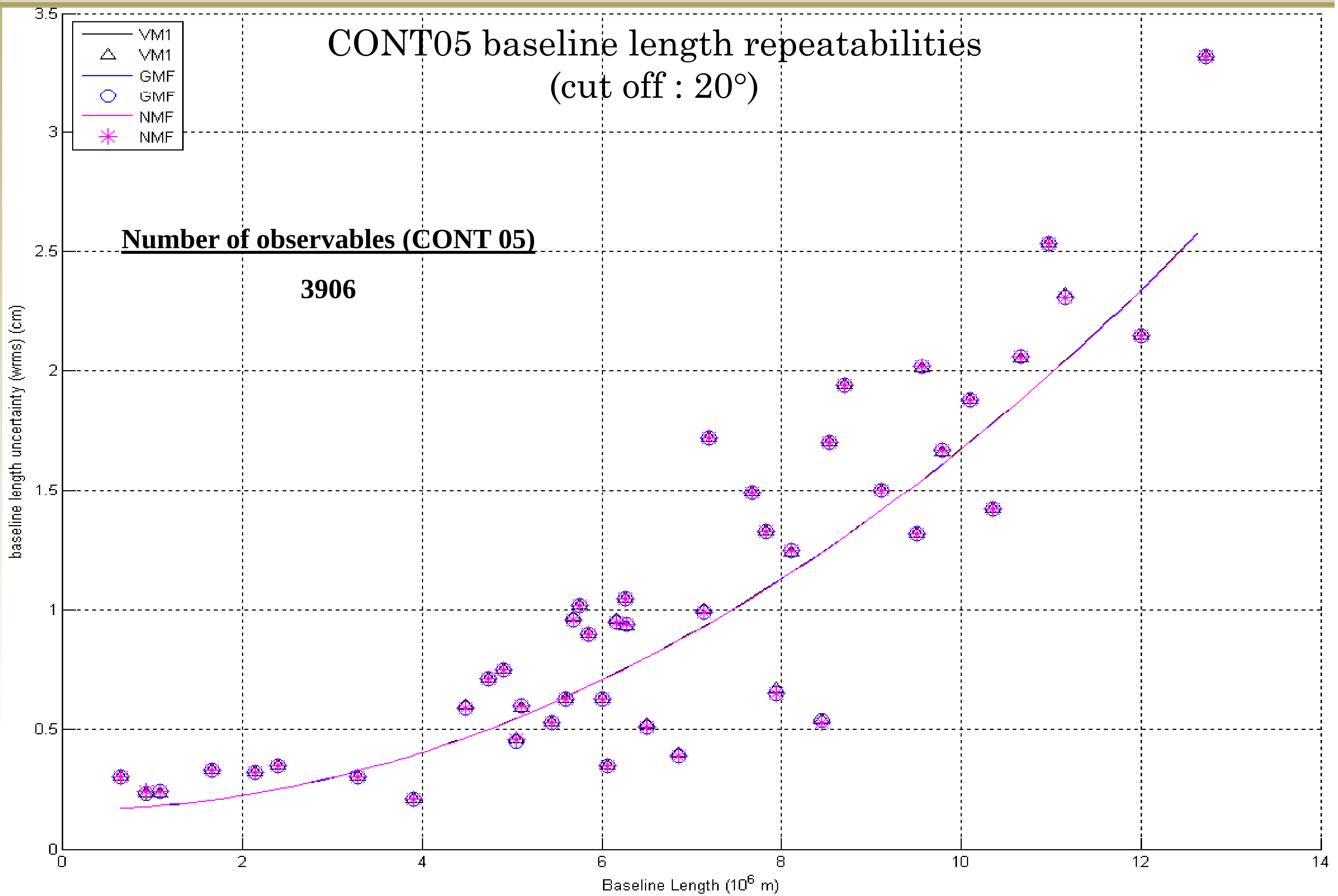
Different Tropospheric Mapping Functions and Cut off Angles Investigated by Processing VLBI CONT05 Sessions



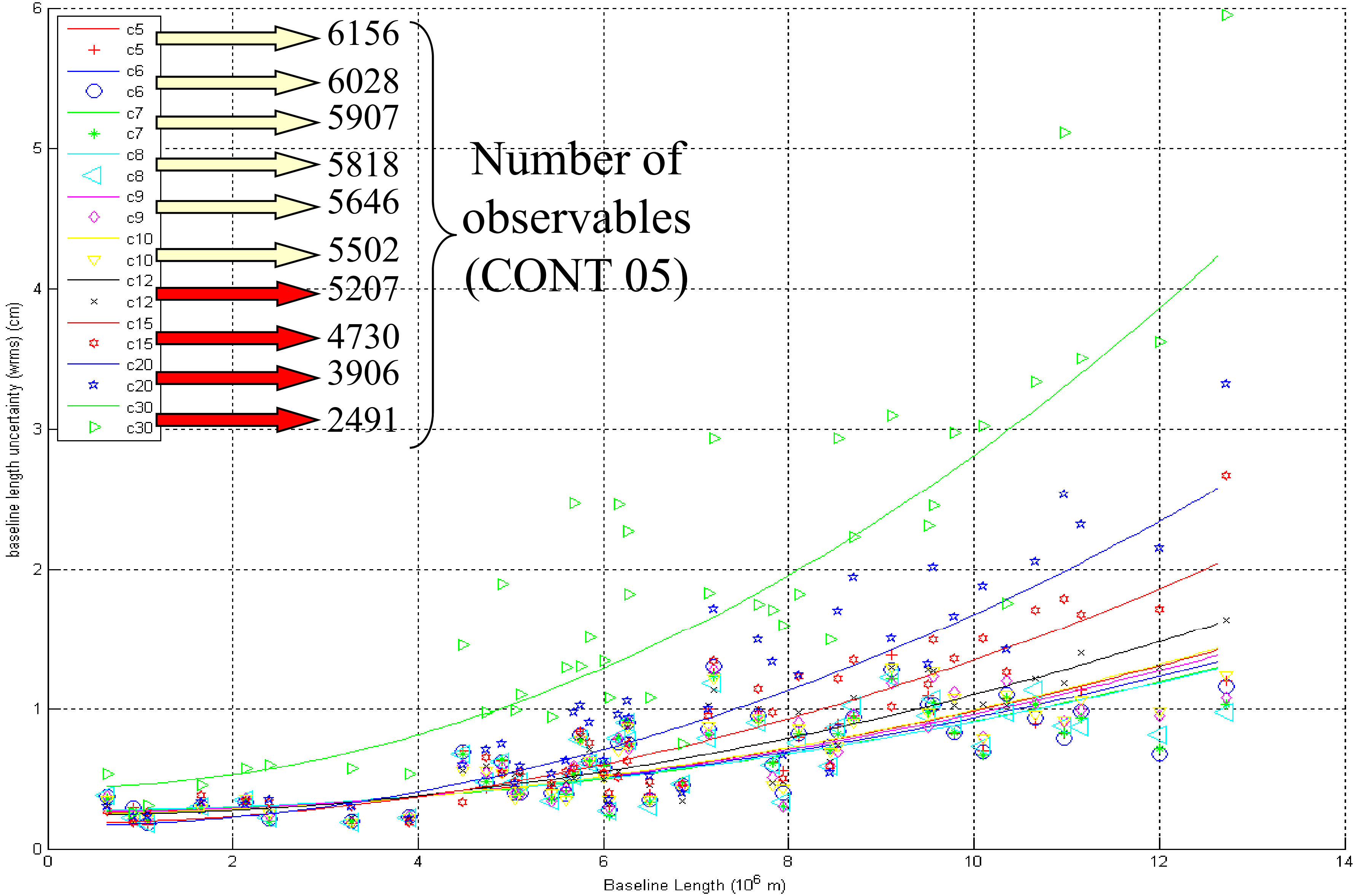
Different Tropospheric Mapping Functions and Cut off Angles Investigated by Processing VLBI CONT05 Sessions



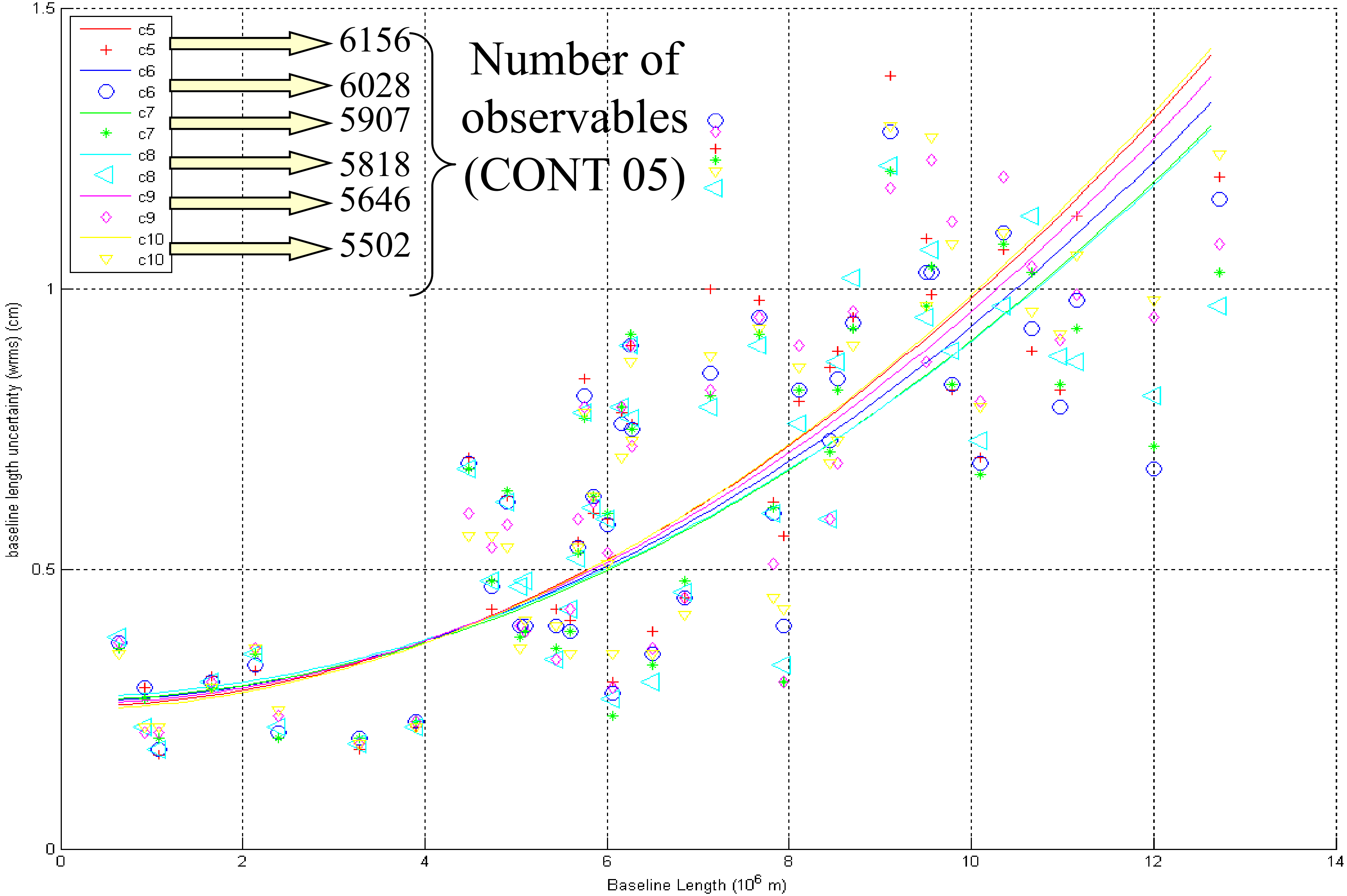
Different Tropospheric Mapping Functions and Cut off Angles Investigated by Processing VLBI CONT05 Sessions



CONT05 baseline length repeatabilities (VMF1)



CONT05 baseline length repeatabilities (VMF1)

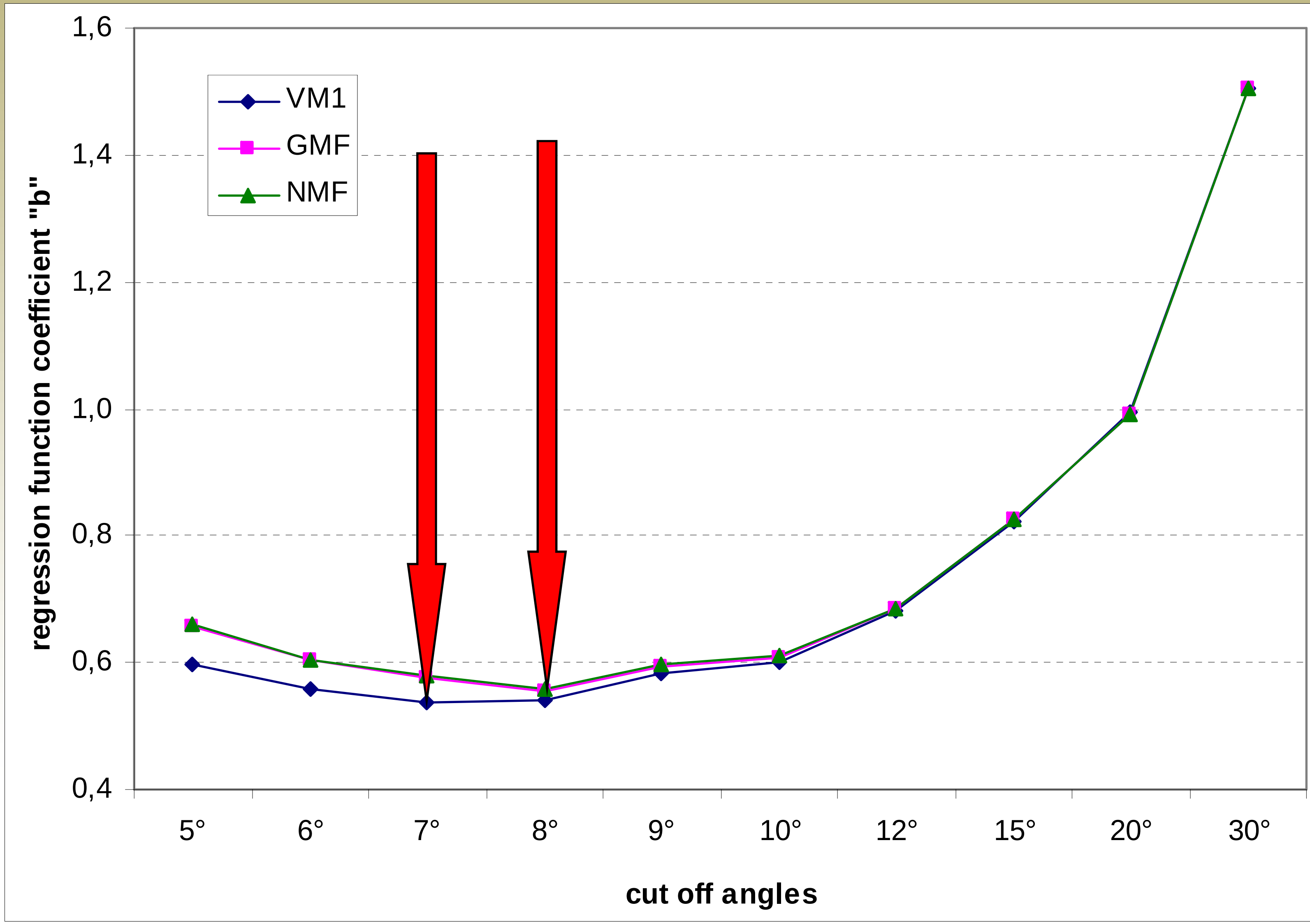


Values of the estimated parameters by LSM

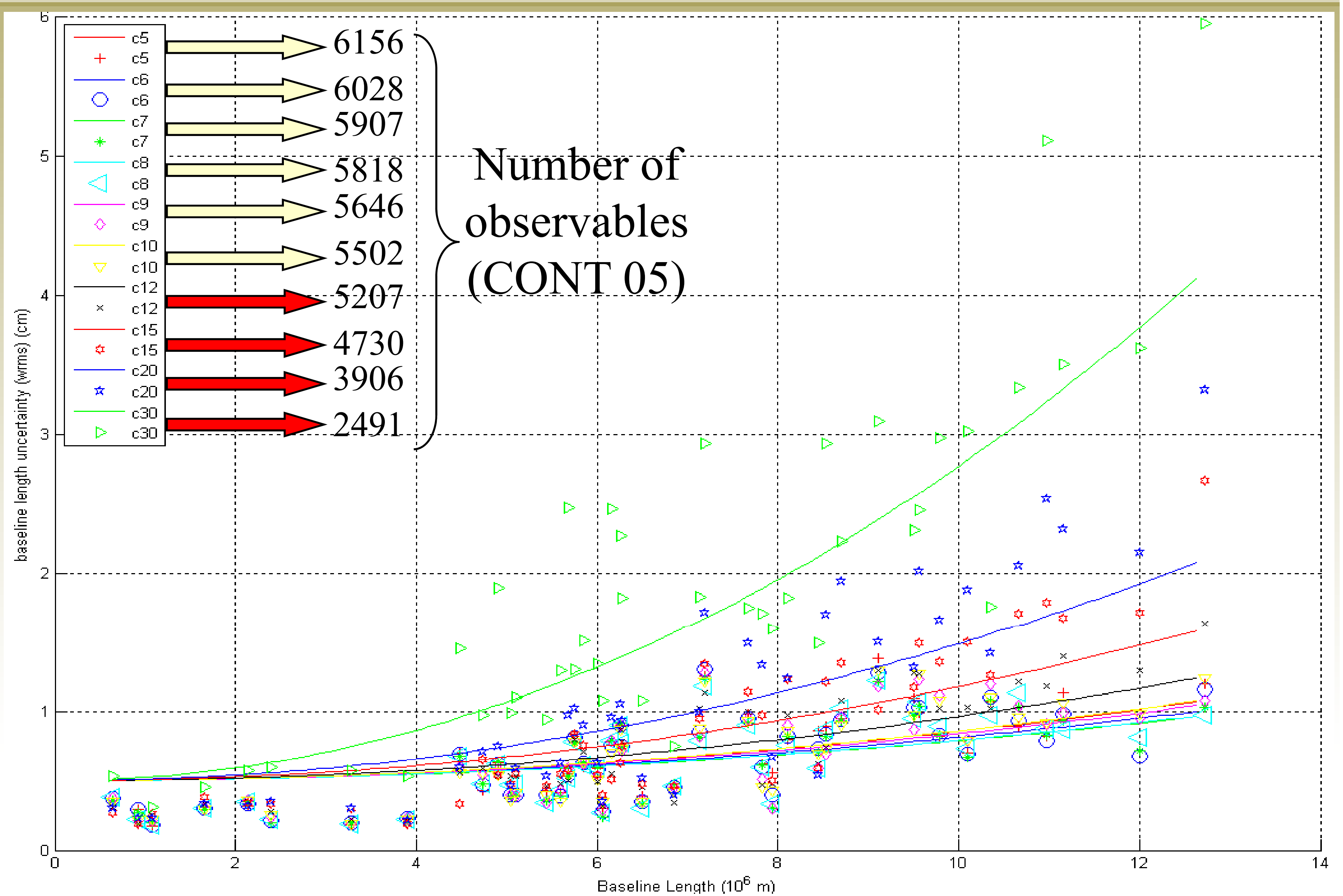
Parameter “a“ fixed to 0.5 cm

Mapping Functions	Parameters of the function for different cut off angles									
	5 5°(6156)		3 6°(6028)		1 7°(5907)		2 8°(5818)		4 9°(5646)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VMI	0,5	0,597	0,5	0,559	0,5	0,537	0,5	0,540	0,5	0,582
GMF	0,5	0,657	0,5	0,605	0,5	0,577	0,5	0,554	0,5	0,595
NMF	0,5	0,660	0,5	0,605	0,5	0,580	0,5	0,558	0,5	0,597
Mapping Functions	6 10°(5502)		12°(5207)		15°(4730)		20°(3906)		30°(2491)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VMI	0,5	0,600	0,5	0,680	0,5	0,823	0,5	0,994	0,5	1,506
GMF	0,5	0,610	0,5	0,685	0,5	0,824	0,5	0,993	0,5	1,505
IMF	0,5	0,611	0,5	0,686	0,5	0,826	0,5	0,992	0,5	1,506

Comparison of the parameter “b“



CONT05 baseline length repeatabilities (VMF1) Parameter “a“ fixed to 0.5 cm



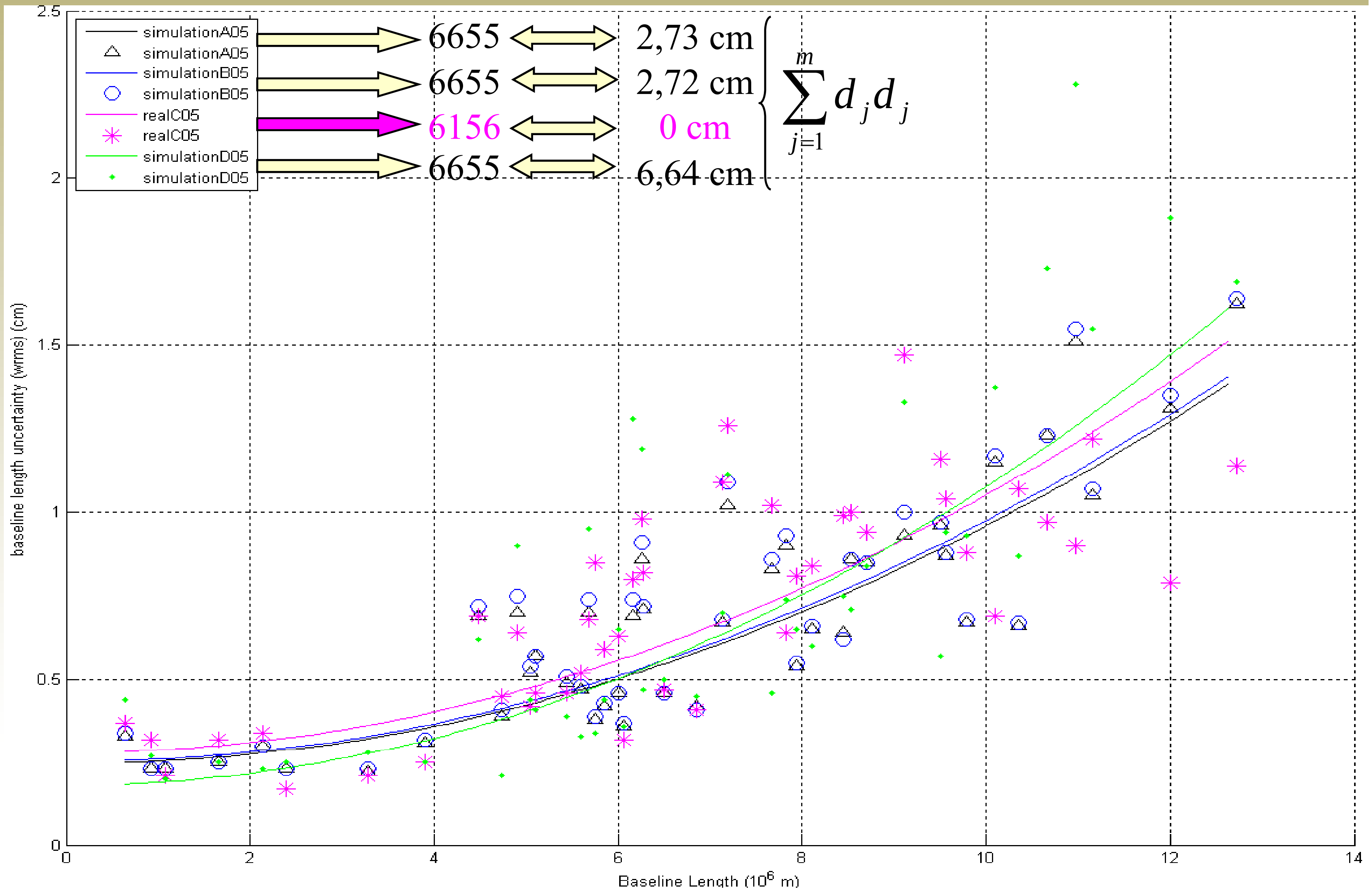
Simulation Formula

$\Delta\tau$: Observed group delay is simulated

$$\Delta\tau = \Delta\tau_{computed} + (WZD_2\ mfw_2(e) + cl_2) - (WZD_1\ mfw_1(e) + cl_1) + wn_{bsl(1-2)}$$

$$\sum_{j=1}^{m}(rep_{real(j)} - rep_{simulated(j)})^2 \Rightarrow \min$$

Comparison of baseline length repeatabilities derived from simulated and real CONT05 NGS files



Simulation Results

Parameters	Simulations					
	1st Simulation (A05)		2nd Simulation (B05)		3rd Simulation (D05)	
white noise	8psec (2.4 mm)		12psec (3.6mm)		8psec (2.4mm)	
predicted clock	1e-15@15min		1e-15@15min		1e-15@15min	
predicted wet zenith delay	Station	PSD (psec^2/sec)	Station	PSD (psec^2/sec)	Station	PSD (psec^2/sec)
	HARTRAO	0.1	HARTRAO	0.1	All stations	0.5
	KOKEE	0.8	KOKEE	0.8		
	TSUKUB32	0.6	TSUKUB32	0.6		
	The rest of all stations	0.5	The rest of all stations	0.5		

Conclusions

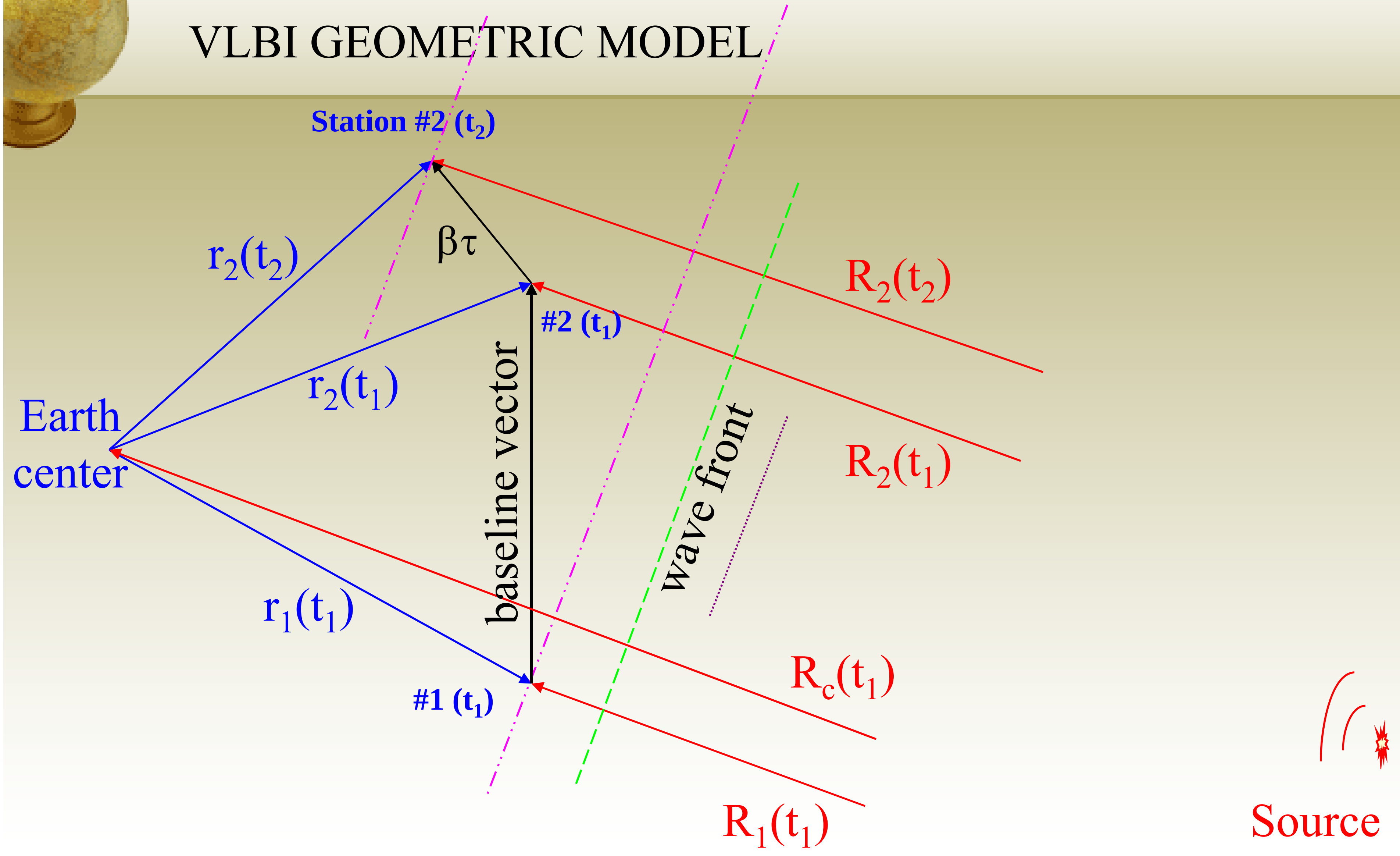
- Similar baseline uncertainty values for cut off angles 5 to 10 degrees but not for 12 to 30 degrees.
- Inspite of the small differences, VM1 gives always the best results.
- If the same amount of observables for simulations with the real ones, cut off angle 7 gives approximately the best outcomes.
- It has been succeeded to create overlapped simulation outcomes with the real ones for cut off angle 7 degree.

Outlook

- No need to observe quasars below the cut off angle 7 unless the wet zenith delay parameters will be measured accurately and the related models will be improved.
- Future simulations should use the turbulence model for the wet zenith delays.
- Down-weighting of low elevation observations should be tested.

Thank You ...

VLBI GEOMETRIC MODEL



$$c\tau = c(t_2 - t_1) = \left| R_C(t_1) + r_2(t_1) + \beta\tau \right| - \left| R_C(t_1) + r(t_1) \right|$$