Monitoring UT1 using VLBI and GPS estimates

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Outline

1 – Combinations of astro-geodetic technique for Earth Rotation

Status of the art

2 – What is the contribution of VLBI to IERS EOP ?

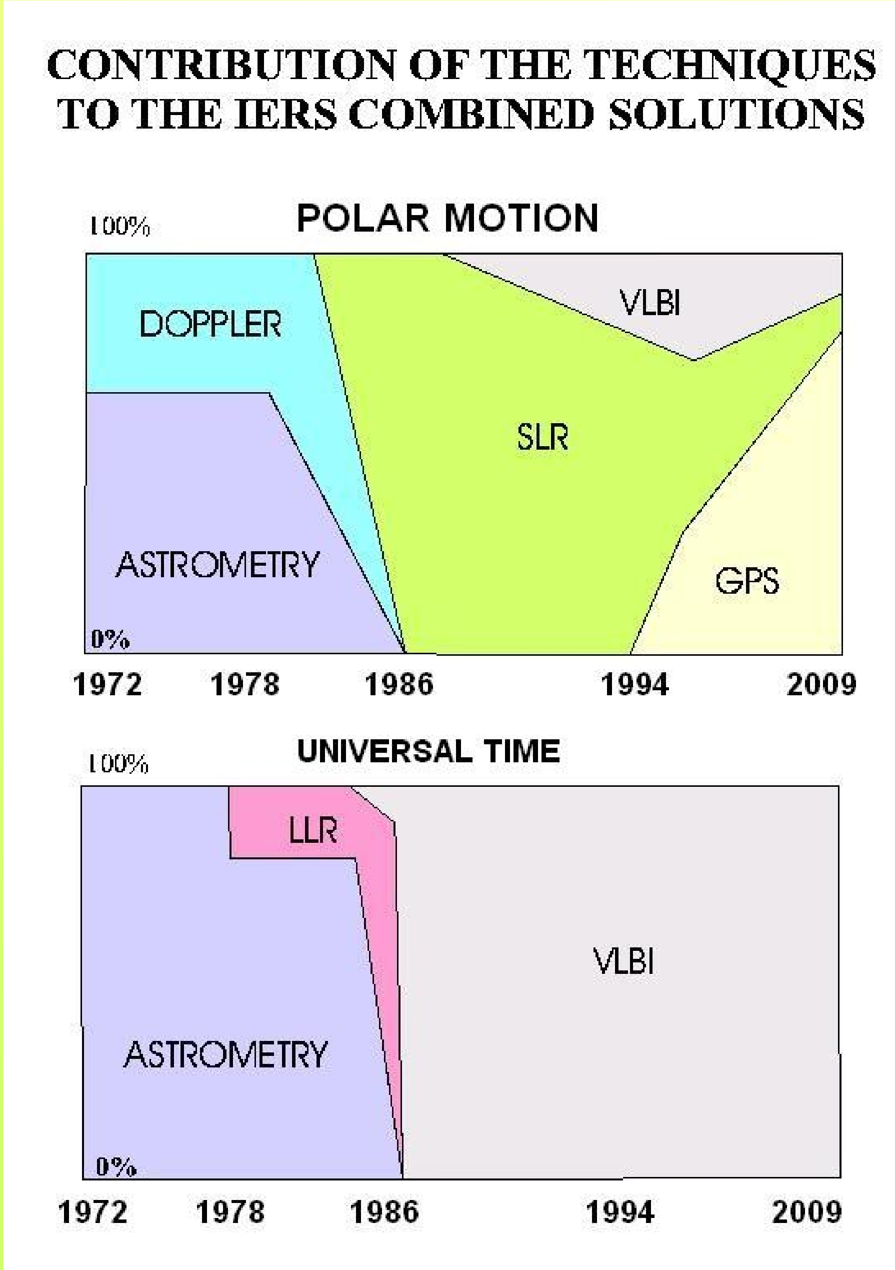
Statistics, analyses and comparisons of different ACs series

R1, R4, INT1, INT2

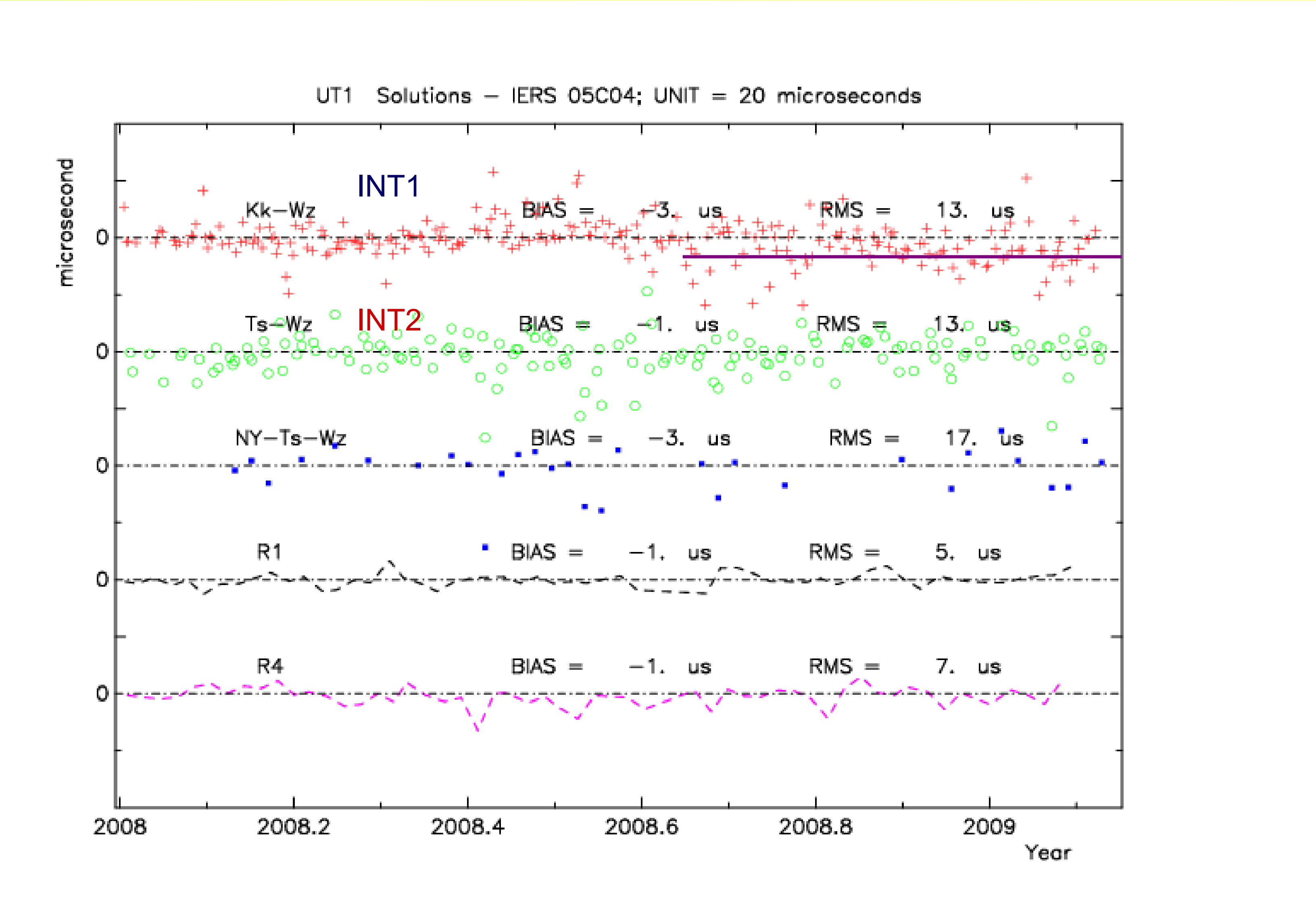
3 – Use of LOD GPS in UT1 estimation

Techniques contributing to IERS, evolution with time

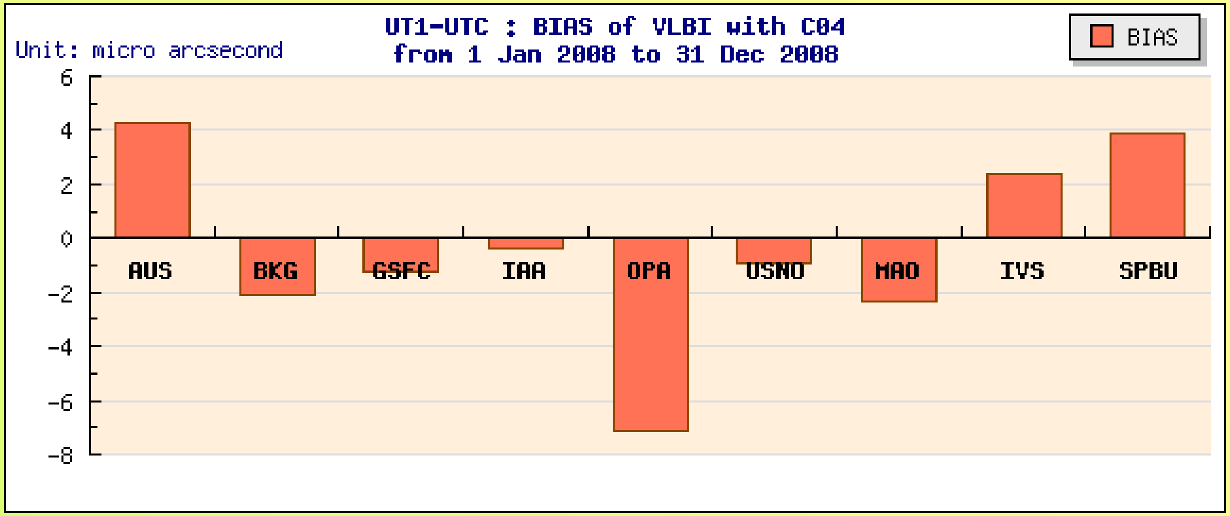
Technique	*since*	*EOP*	*Time Res.*	*Present accuracy*	
ASTROMETRY	1899	Pole	5 days	Pole:	20 mas
		UT1	“	UT1:	1 ms
		Nutation	“	Nutation:	40 mas
DOPPLER	1972	Pole	2 days	Pole:	4 mas
LLR	1969	UT0	1 day	UT0:	0.1 ms
SLR	1976	Pole	3 days	Pole:	200µas
		LOD	“	LOD:	200 µs
VLBI	1981	Pole	3 days	Pole:	100 µas
		Nutation	“	Nutation:	60 µas
		UT1	sub-daily - 1 day	UT1:	5 µs
GPS	1993	Pole	sub-daily	Pole:	30 µas
		LOD	“	LOD:	8 µs
DORIS	1995	Pole	3 days	Pole:	1 mas

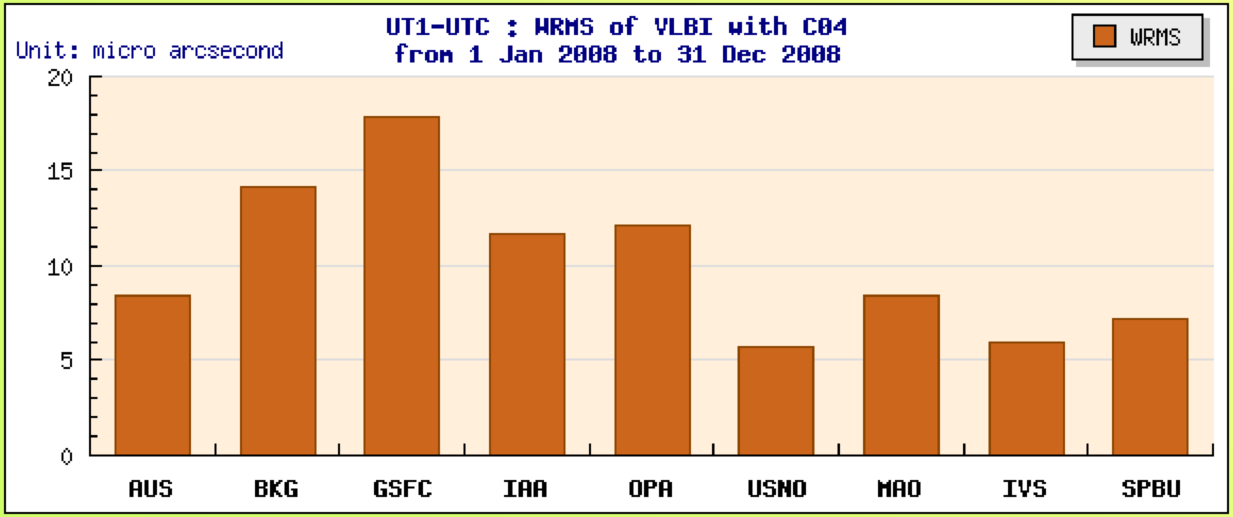

CONTRIBUTION OF THE TECHNIQUES
TO THE IERS COMBINED SOLUTIONS
POLAR MOTION
100%
DOPPLER
VLBI
SLR
ASTROMETRY
GPS
0%
1972
1978
1986
1994
2009
UNIVERSAL TIME
100%
LLR
VLBI
ASTROMETRY
0%
1972
1978
1986
1994
2009

Comparisons INT1, INT2 , R1 and R4 to C04

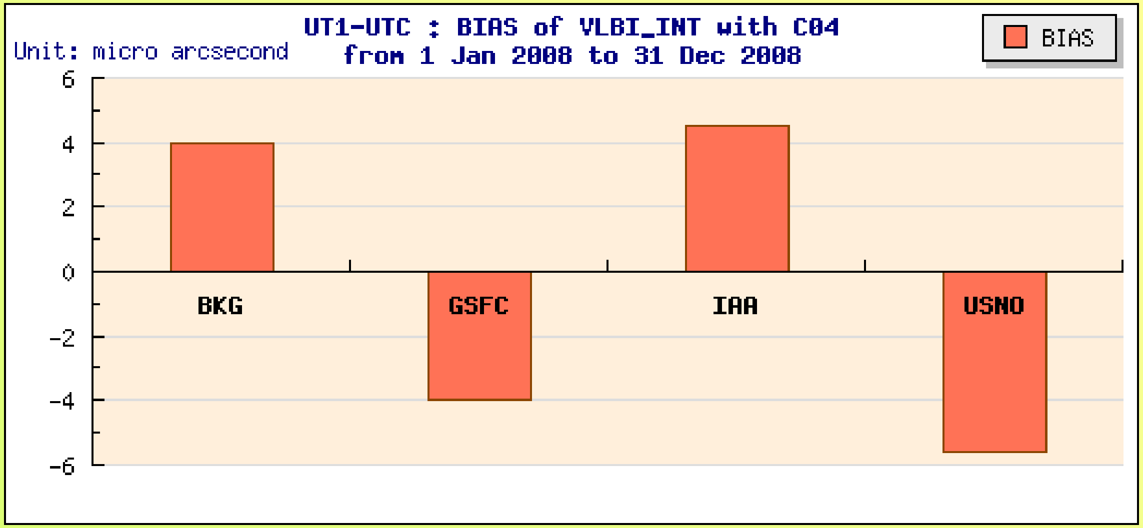


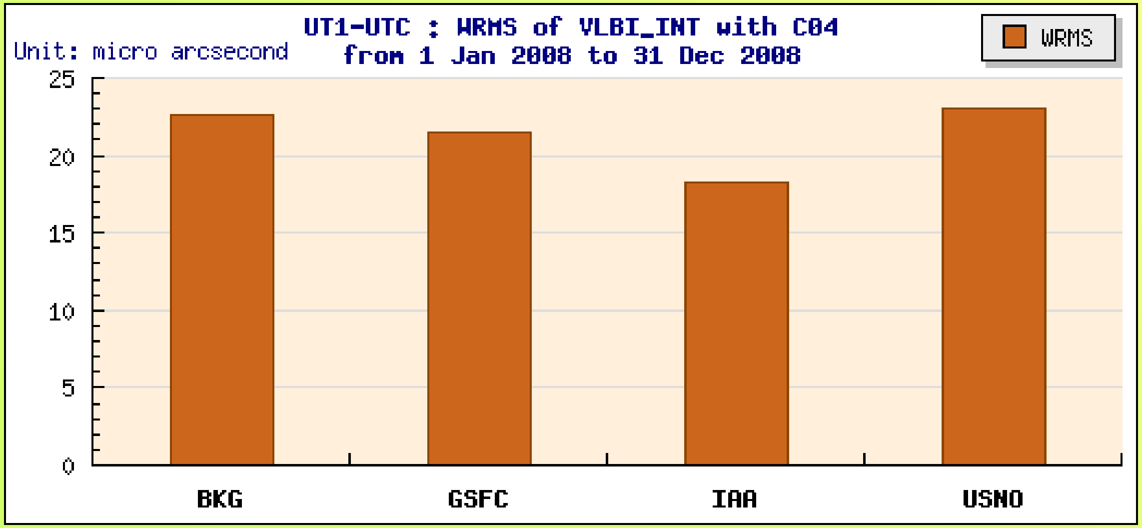
VLBI standard, UT1





VLBI intensive, UT1





USE of LOD(GPS) for UT1

Data

- UT1 standard VLBI sessions
  - Series from VLBI ACs (AUSLIG, GSFC, IAA, USNO, OPA,IAA, SPBU), GSFC R1 and R4
- UT1 , intensive sessions
- Daily LOD from IGS (igs00p03),
  - 12h epochs,
  - Problem of systematic biaises due to GPS orbit mis-modeling
- Integration of LOD can be used
  - Densification
  - Correct when VLBI intensive are erroneous (50-100 μs possible)
  - Fill gaps when UT1 intensive are missing (sometimes 4-5 days)
  - Quasi-real time estimates (last VLBI intensive epoch to now)

Method of Combined smoothing

- UT1 is observed by VLBI with a high long-term accuracy stability, with not high resolution (3/4 days), 5-8 μs
- UT1 intensive 15-20 μs
- LOD is observed by satellite methods with a short-term accuracy (10 μs) and high resolution (1 day)
- LOD first derivative of UT1 LOD=-d (UT1-TAI)/dt

Method of Combined smoothing

- Two relatively smooth curves
  - a) One fitting well to VLBI UT1 estimates
  - b) Second one fitting well to GPS LOD estimates
  - Both curves tied by constraints: latter is the first derivative of the former

- Combined smoothing is a generalization of Vondrak's smoothing

(Vondrak and Gambis, 1999; Vondrak and Cepek, 2000)

Compromise between 3 conditions:

we define the values:

1.
$$S = \frac{1}{x_n - x_1} \int_{x_1}^{x_n} [\varphi'''(x)]^2 \, dt$$

'smoothness' of the first curve, where φ is estimated from Lagrange polynomial fitted to four consecutive points on the smoothed curve;

observed smoothed

2.
$$F = \frac{1}{n-3} \sum_{1}^{n} p_i (y_i' - y_i)^2$$

'fidelity' of the first curve to the observed values;

observed smoothed

3.
$$\bar{F} = \frac{1}{n-3} \sum_{1}^{n} \bar{p}_j (\bar{y}_j' - \bar{y}_j)^2$$

'fidelity' of the second curve to the observed first derivatives;

and we express the values $\bar{y}_j$ in terms of y_i (from the first derivatives of the same Lagrange polynomial defining smoothness S above)

⇒ constraints assuring that the second curve is the time derivative of the first one, of the general form

$$\bar{y}_j = \sum_{i=1}^{n} a_i y_i$$

We are looking for the 'smoothed' function values y_i and the first derivatives $\bar{y}_j$ as a (weighted) compromise among three conditions:

a) the curve should be smooth (minimizing S);

b) the values y_i should be close to the observed values of the function (minimizing F);

c) the values $\bar{y}_j$ should be close to the observed values of the first derivative (minimizing $\bar{F}$);

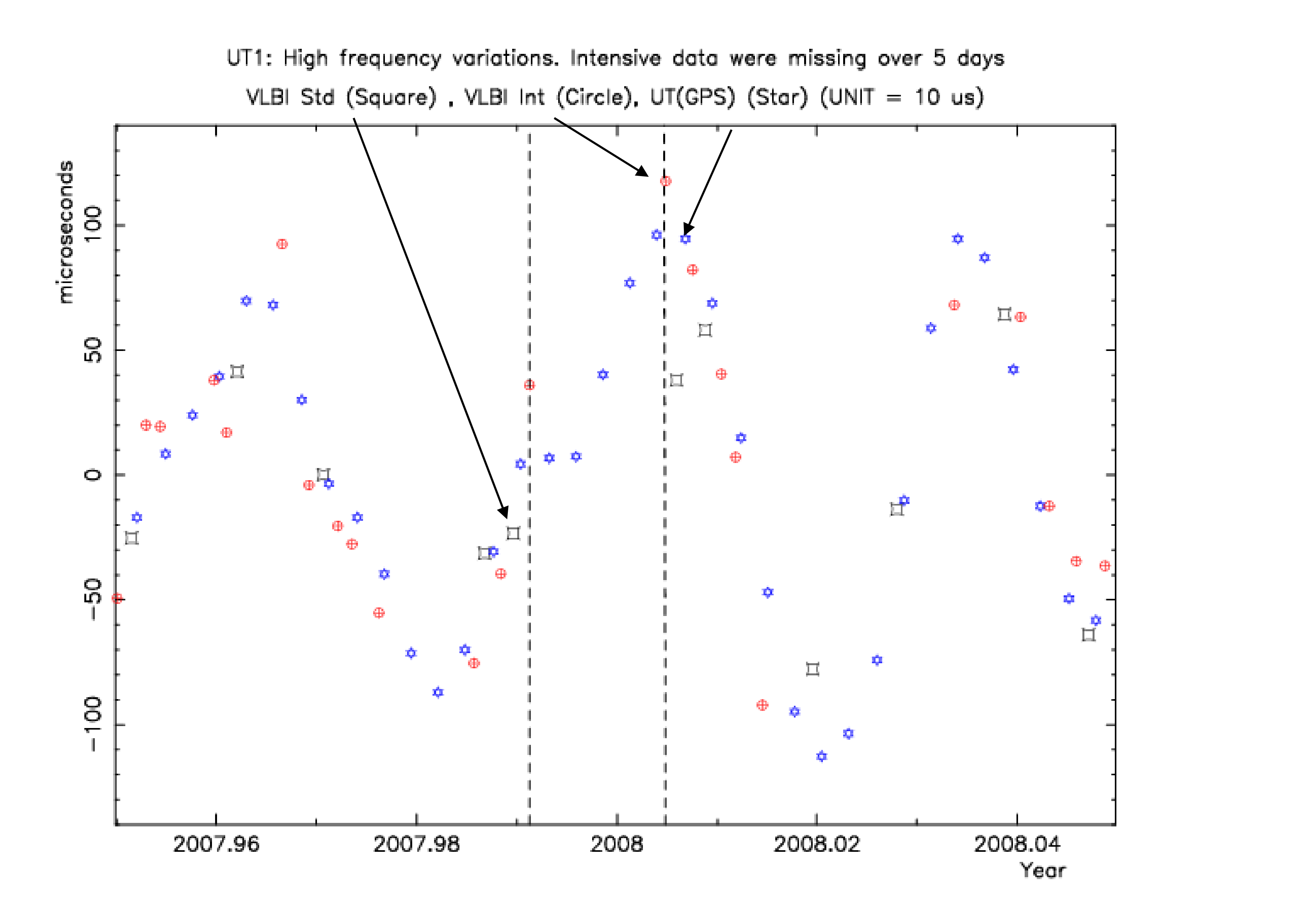
d) the values y_j, $\bar{y}_j$ are tied by the constraints above.

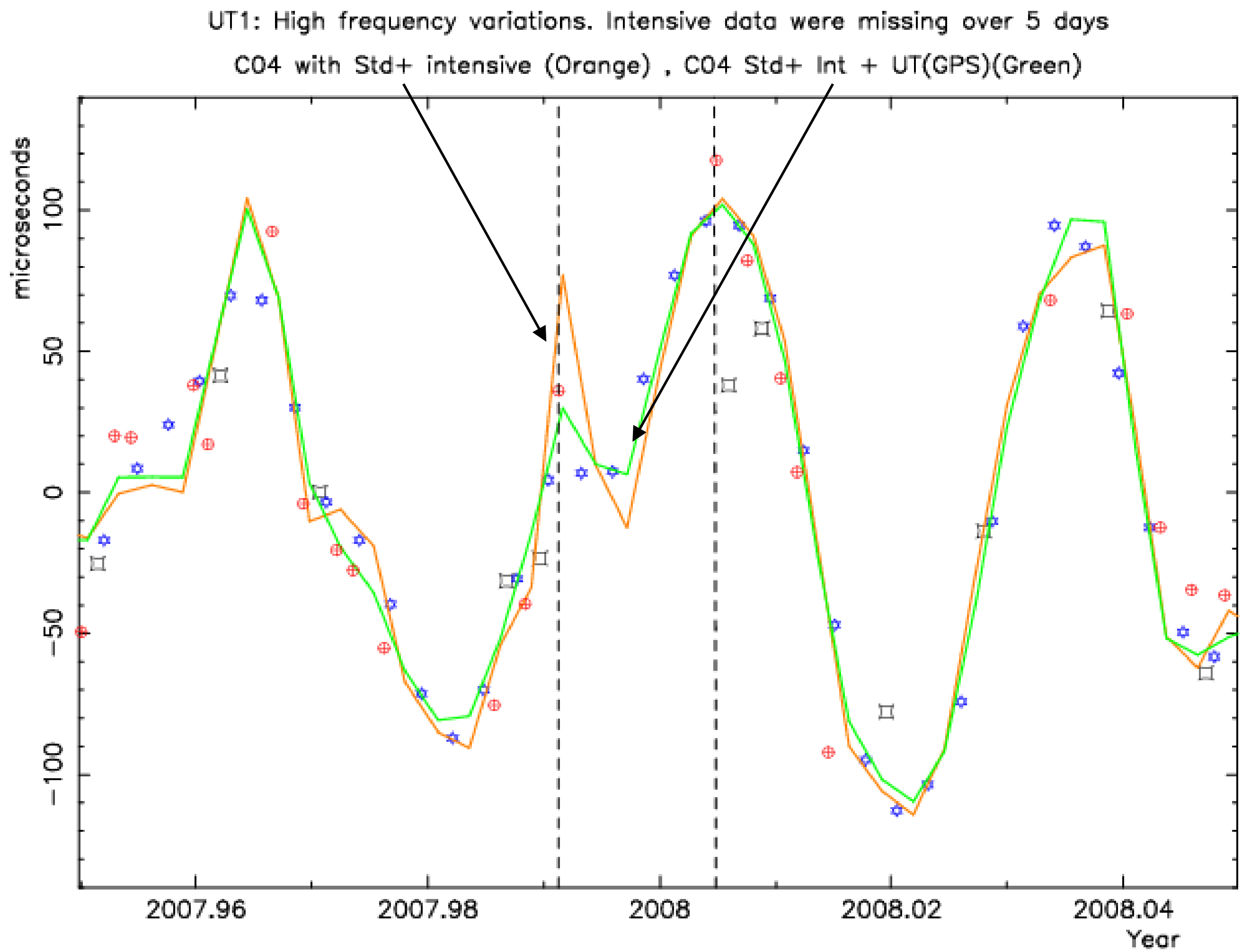
$\Longrightarrow$ Adjustment by minimizing the expression

$$Q = S + \varepsilon F + \bar{\varepsilon}\bar{F} = \min.$$

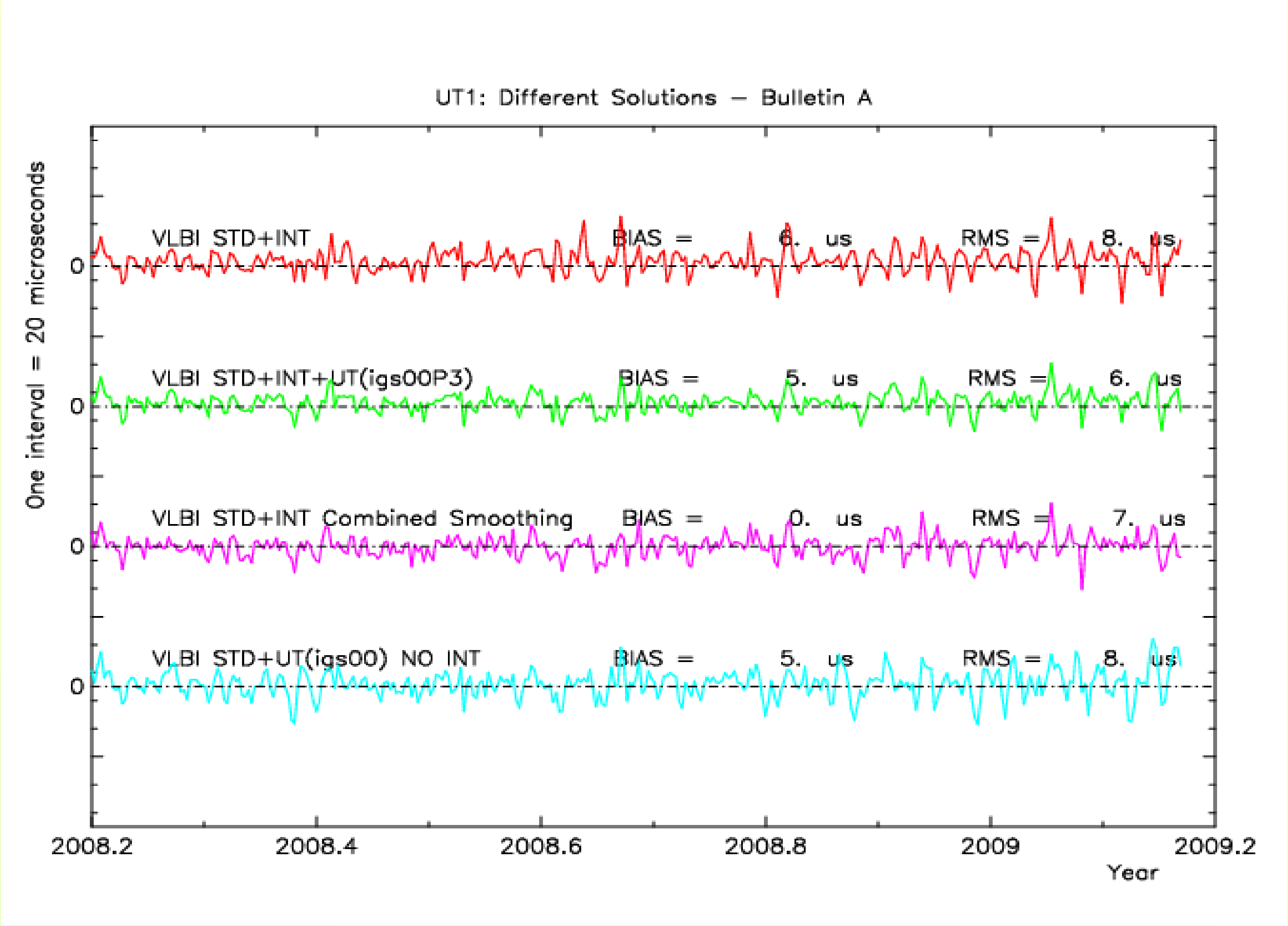
$$\Rightarrow \frac{\partial Q}{\partial y_i} = 0$$

leading to the system of n linear equations (whose matrix is symmetric, with only 7 non-zero diagonals) for the unknowns y_i; the values $\bar{y}_j$ can be then easily calculated from the constraints.


UT1: High frequency variations. Intensive data were missing over 5 days
VLBI Std (Square) , VLBI Int (Circle), UT(GPS) (Star) (UNIT = 10 us)
microseconds
100
50
0
−50
−100
2007.96
2007.98
2008
2008.02
2008.04
Year


UT1: High frequency variations. Intensive data were missing over 5 days
C04 with Std+ intensive (Orange) , C04 Std+ Int + UT(GPS)(Green)
microseconds
100
50
0
−50
−100
2007.96
2007.98
2008
2008.02
2008.04
Year

Comparison of various UT1 series to BULLETIN A



CONCLUSIONS

- Current accuracy in the range of 5 μs for Standard, 15-20 μs for Intensive
- However, in case of erroneous data or gaps, UT(GPS) can be valuable to densify and homogenize UT1 estimates
- Combined smoothing using LOD(GPS) allows to improve the combination of UT1 and LOD
- Consistency of UT1 and LOD
- UT1: Gain of only 3 μs (45 μas) when using intensive!!