Fundamentals on UTC
Relationship between GNSS times

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4th ICG, 14-18 September 2009, St Petersburg

Outline of presentation

- Definition of international time scales
  - UTC
  - TAI
  - Leap second
- Relation between satellite time scales
  - GPS time
  - Glonass time
  - Galileo system time
  - COMPASS system time

  …

Unification of time

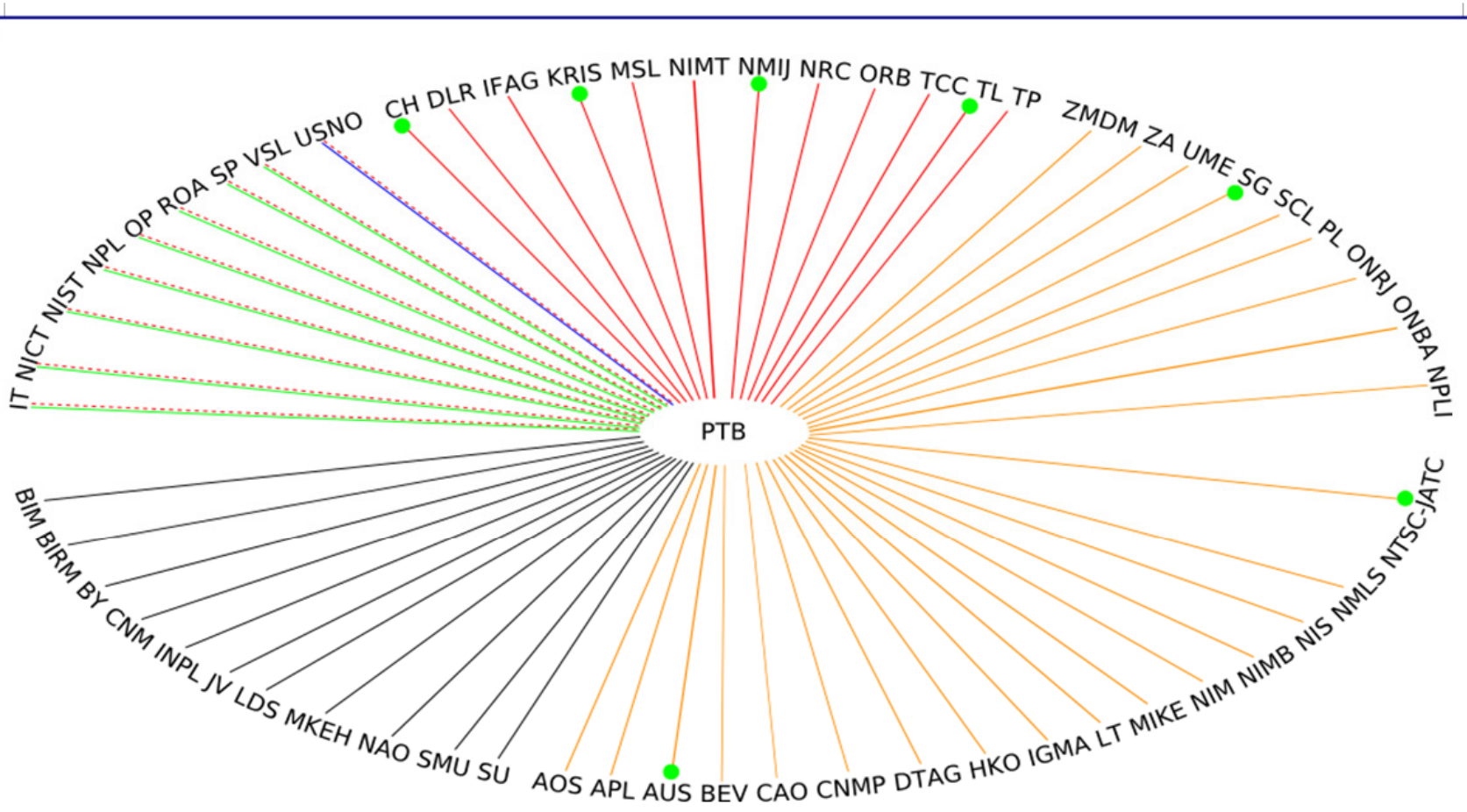
- **1884 - Adoption of a prime meridian Greenwich and of an associated time - universal time, based on the rotation of the Earth.**
- **1948 - *International Astronomical Union* recommends the use of Universal Time (UT).**
- **1968 - *13th General Conference of Weights and Measures* adopted a definition of SI second, based on a caesium transition, and opened the way toward the formal definition of International Atomic Time (TAI).**
- **1971 - *International Astronomical Union, International Telecommunications Union, General Conference of Weights and Measures* recommend the use of Coordinated Universal Time (UTC) based on TAI. Introduction of leap seconds.**
- **2003 - Use of leap seconds under revision**

Coordinated Universal Time (UTC)

- **UTC is computed at the BIPM and made available every month in the BIPM *Circular T* through the publication of [*UTC – UTC(k)*]**
  - **International Atomic Time (TAI) is based on the readings of about 400 atomic clocks located in metrology institutes in about 45 countries around the world. TAI has scientific applications and is not represented by clocks. Consequently is not used for time dissemination.**
  - **UTC = TAI corrected for 1 second time steps (TAI - UTC = 33s today)**
- **Local realizations of UTC named UTC(k) are broadcast by time signals**
- **UTC is the basis for legal time worldwide**

Local realizations of UTC

- UTC(k)
  - ✓ Local realization of UTC at laboratory k (62 at present)
  - ✓ [*UTC*-*UTC*(*k*)] < 100 ns (recomm.)
  - ✓ Dissemination by time signals (recommendations ITU-R)
  - ✓ [*UTC*-*UTC*(*k*)] published in BIPM Circulaire T (one value every 5 days), monthly
  - ✓ Some UTC(k) are represented by a clock (plus eventually a micro-phase stepper)
  - ✓ Some UTC(k) are evaluated from a clock ensemble



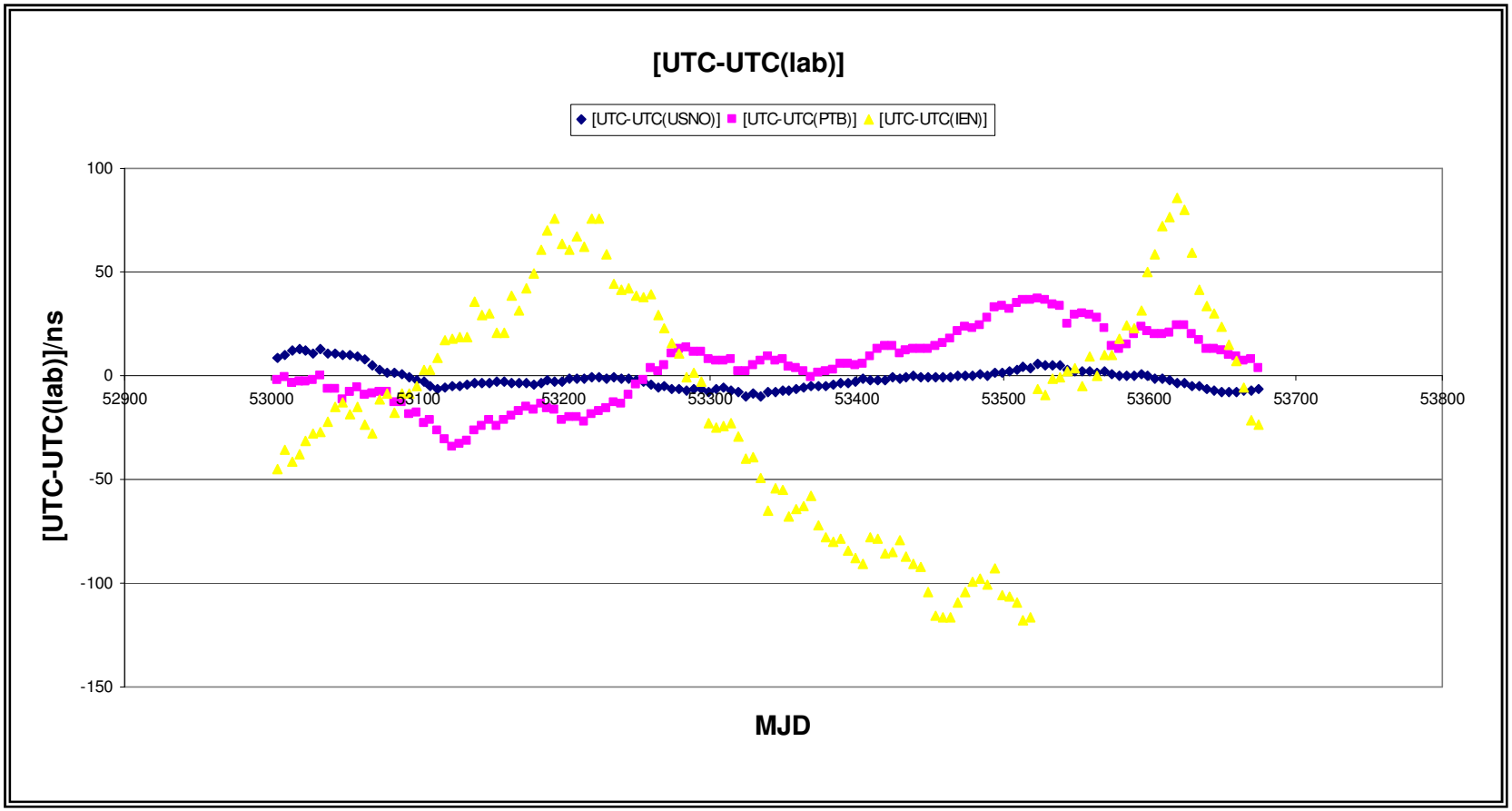
ORGANIZATION OF THE ALL-IN-VIEW INTERNATIONAL TIME LINKS April 2007

●	Laboratory equipped with TWSTFT (not yet used)		
———	TWSTFT by Ku band with X band back-up	———	GPS AV multi-channel link
———	TWSTFT link	- - - -	GPS AV multi-channel back-up link
———	GPS AV single-channel link	———	GPS AV dual frequency link
- - - -	GPS AV single-channel back-up link	- - - -	GPS AV dual frequency back-up link

CIRCULAR T 223 ISSN 1143-1393
2006 AUGUST 10, 14h UTC

BUREAU INTERNATIONAL DES POIDS ET MESURES

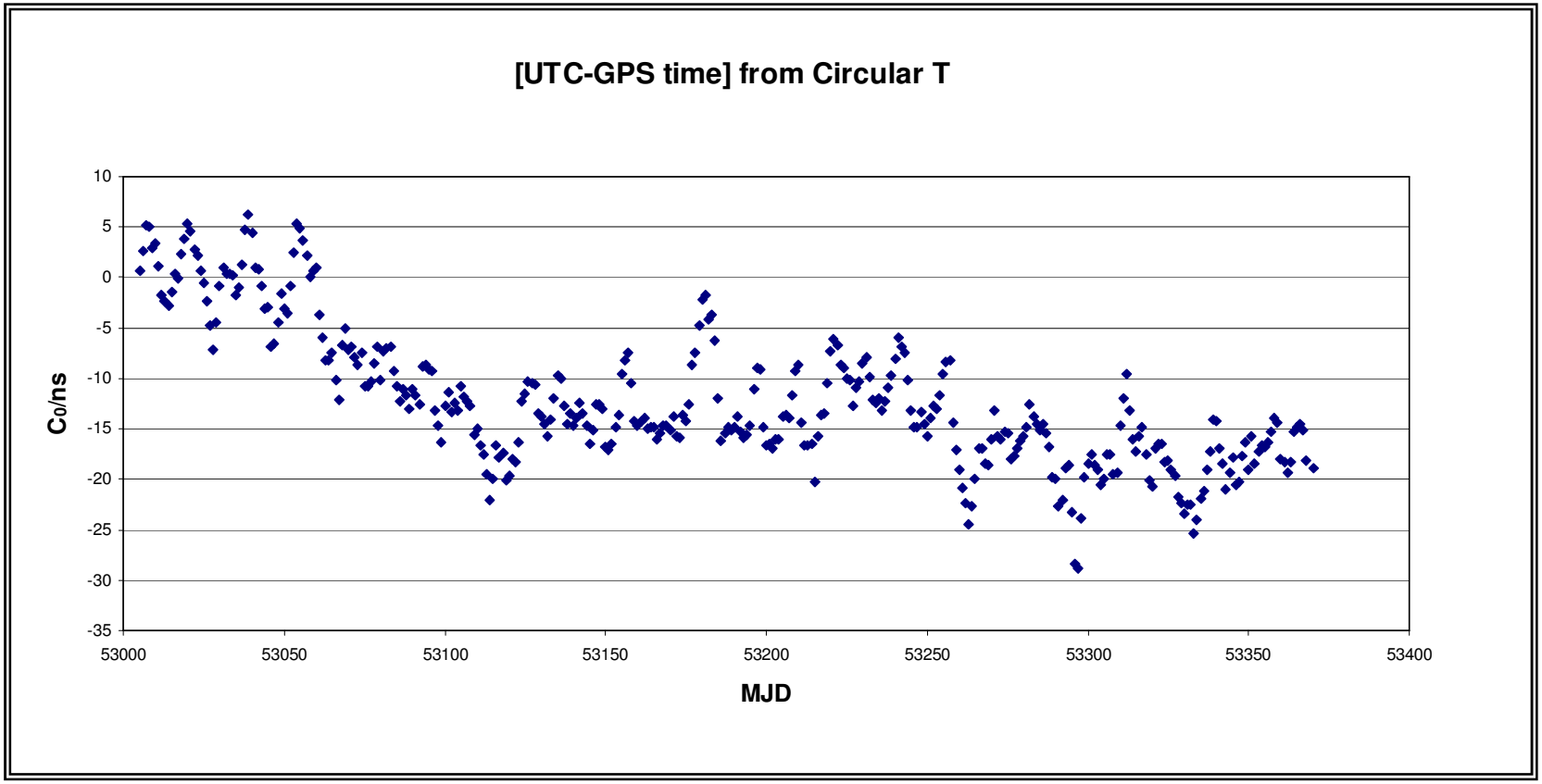
Date 2006 0h UTC	JUN 28	JUL 3	JUL 8	JUL 13	JUL 18	JUL 23	JUL 28	Uncertainty/ns		
MJD	53914	53919	53924	53929	53934	53939	53944	uA	uB	u
Laboratory k	[UTC-UTC(k)]/ns									
AOS (Borowiec)	5.2	9.3	3.3	6.2	10.6	7.1	9.9	1.6	5.3	5.5
APL (Laurel)	0.8	4.6	-0.7	-3.4	-4.3	3.7	15.4	1.6	5.2	5.4
AUS (Sydney)	-529.0	-498.6	-490.1	-489.2	-475.2	-445.1	-437.4	3.2	6.3	7.1
BIRM (Beijing)	-1874.4	-1893.8	-1898.2	-1913.1	-1930.8	-1946.6	-1964.5	2.8	20.4	20.6
CH (Bern)	30.9	31.3	36.1	32.2	29.9	25.1	21.5	0.8	5.2	5.3
IT (Torino)	-5.0	-5.2	-3.4	-4.6	-3.6	-2.8	-1.1	0.7	2.2	2.3
KRIS (Daejeon)	-14.6	-5.4	-4.0	-8.2	-1.6	2.2	-0.3	1.4	6.3	6.5
LT (Vilnius)	147.0	153.3	145.7	138.2	149.2	161.1	143.2	1.6	5.3	5.5
NICT (Tokyo)	-8.1	-11.4	-7.6	-8.1	-5.8	-5.2	-0.7	1.2	3.9	4.1
NIST (Boulder)	9.2	8.3	9.2	8.6	8.1	6.7	6.5	0.7	4.9	5.0
NMIJ (Tsukuba)	-10.3	-11.3	-8.1	-8.3	-7.1	-3.0	0.4	1.4	6.3	6.5
NPL (Teddington)	7.9	4.9	5.2	3.4	1.1	0.6	0.5	0.7	2.2	2.3
NPLI (New-Delhi)	119.6	138.9	154.2	169.9	-119.2	-108.5	-94.9	2.5	7.2	7.6
NRC (Ottawa)	-27.1	-21.3	-26.3	-32.7	-33.7	-28.9	-30.3	3.0	15.1	15.4
NTSC (Lintong)	10.4	7.1	5.1	1.7	-0.8	1.5	7.3	2.6	6.1	6.6
ONRJ (Rio de Janeiro)	7524.1	7568.6	7624.1	7672.2	7726.0	7770.0	7821.6	5.0	20.5	21.1
OP (Paris)	-2.9	-2.8	-2.6	3.8	3.2	5.8	2.4	0.7	2.2	2.3
ORB (Bruxelles)	3.8	2.0	0.1	-3.9	-8.0	-10.0	-7.0	0.8	5.2	5.3
PL (Warszawa)	13.1	11.0	9.0	2.8	12.5	25.5	22.1	1.5	5.0	5.3
PTB (Braunschweig)	25.8	20.8	18.7	17.2	18.2	17.4	13.9	0.5	1.6	1.7
ROA (San Fernando)	63.5	63.4	67.0	61.3	74.6	79.1	69.7	0.8	5.2	5.3
SP (Boras)	25.4	20.1	24.1	25.5	25.6	28.2	25.1	0.8	2.2	2.3
SU (Moskva)	48.1	45.3	45.7	43.6	42.6	43.2	41.1	3.0	5.2	6.0
TL (Chung-Li)	3.1	-0.7	-3.1	-3.8	-7.0	-10.2	-12.1	1.3	6.1	6.3
USNO (Washington DC)	-2.9	-0.3	2.9	3.9	5.3	4.8	5.7	0.5	1.7	1.8
VSL (Delft)	5.6	10.8	5.1	4.3	-3.9	-7.8	-11.6	0.7	3.4	3.4

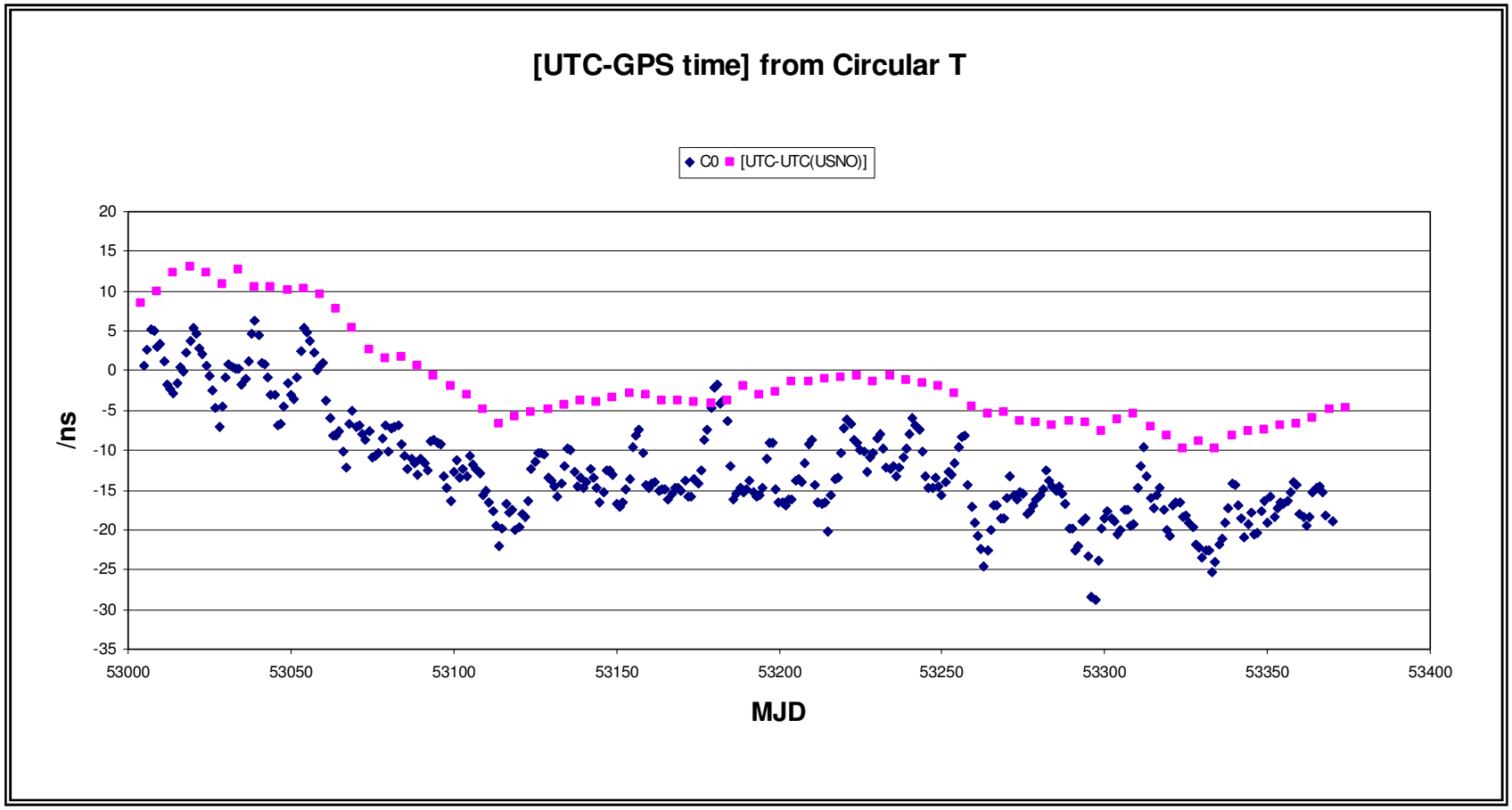

[UTC-UTC(lab)]
[UTC-UTC(USNO)]
[UTC-UTC(PTB)]
[UTC-UTC(IEN)]
100
50
0
-50
-100
-150
52900
53000
53100
53200
53300
53400
53500
53600
53700
53800
[UTC-UTC(lab)]/ns
MJD

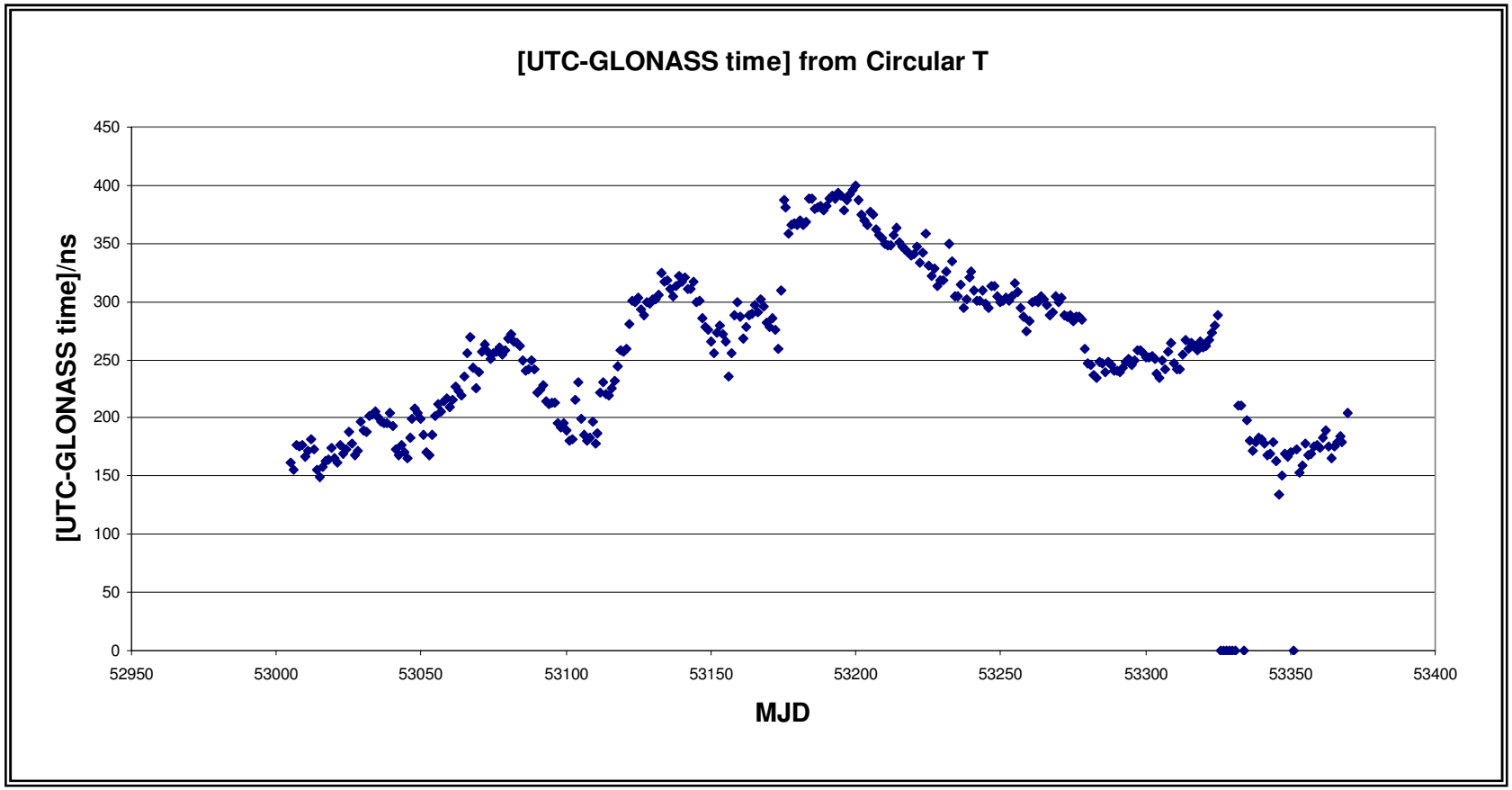
System times

- GNSS times
  - ✓ System times (pseudo-time scales)
  - ✓ Constructed from a clock ensemble
  - ✓ Used for internal system synchronization
  - ✓ Continue (desirable)
  - ✓ Metrologic quality (?)
  - ✓ Steered to a reference time scale

- GPS time
- GLONASS time
- Galileo time
- COMPASS time
- …

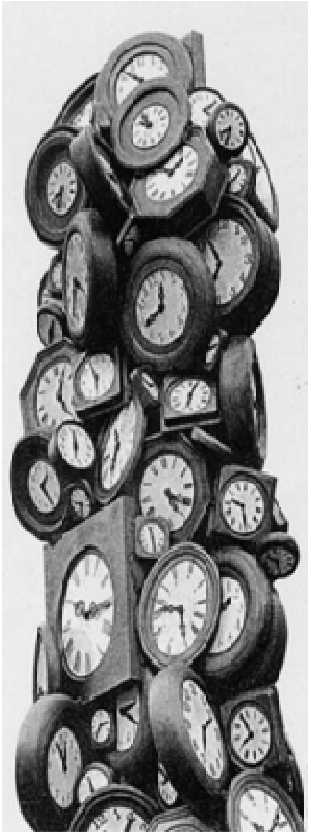

[UTC-GPS time] from Circular T
Co/ns
10
5
0
-5
-10
-15
-20
-25
-30
-35
53000
53050
53100
53150
53200
53250
53300
53350
53400
MJD


[UTC-GPS time] from Circular T
C0
[UTC-UTC(USNO)]
/ns
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
53000
53050
53100
53150
53200
53250
53300
53350
53400
MJD

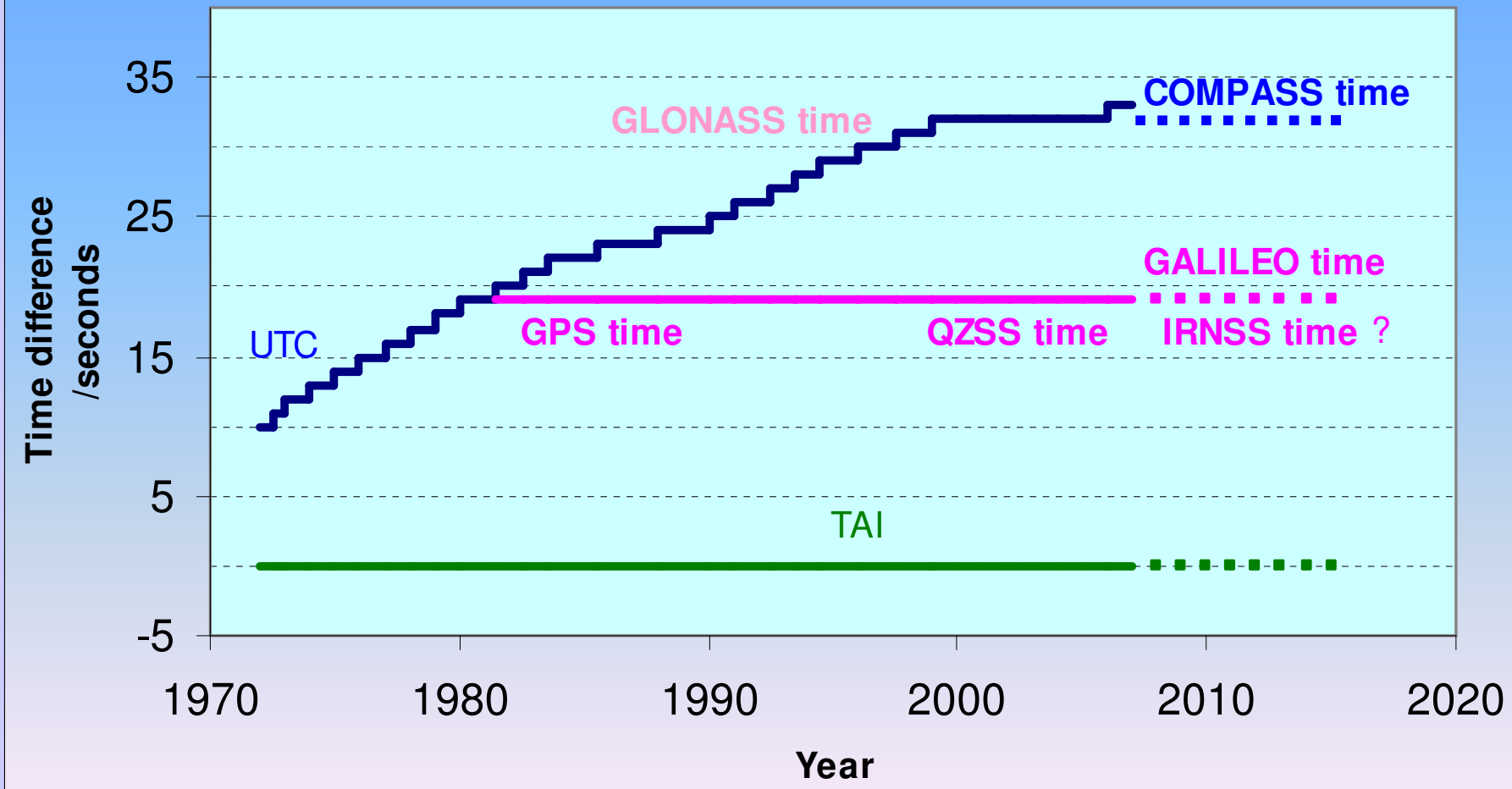

[UTC-GLONASS time] from Circular T
[UTC-GLONASS time]/ns
450
400
350
300
250
200
150
100
50
0
52950
53000
53050
53100
53150
53200
53250
53300
53350
53400
MJD

System times

- GPS time: steered to UTC(USNO) modulo 1s
  - ✓ [TAI – GPS time] = 19 s + C_0
  - ✓ [UTC -GPS time] = -15 s + C_0
  - ✓ $C_0 \leq 20$ ns
  - ✓ Tolerance is 1 µs
- GLONASS time: steered to UTC(SU) with leap second
  - ✓ [TAI – GLONASS time] = 34 s + C_1
  - ✓ [UTC – GLONASS time] = C_1
  - ✓ C_1 ~ some 100 ns
  - ✓ Tolerance is 1 ms
- Galileo time: steered to a set of EU UTC(k); using GPS time seconds, GGTO
  - ✓ [TAI – Galileo time] = 19 s + C_2
  - ✓ [UTC -Galileo time] = -15 s + C_2
  - ✓ Tolerance is 50 ns
- COMPASS time: will be steered to set of Chinese UTC(k)
  - ✓ [TAI –COMPASS time] = 33 s + C_3
  - ✓ [UTC -COMPASS time] = -1 s + C_3
  - ✓ Tolerance is 100 ns



[*TAI - Time scale (i)*]



ITU meeting on redefinition of UTC
Geneva, 8-12 September 2009


MERCI!