

## ***Fundamentals on UTC Relationship between GNSS times***

**E.F. Arias and W. Lewandowski**



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*

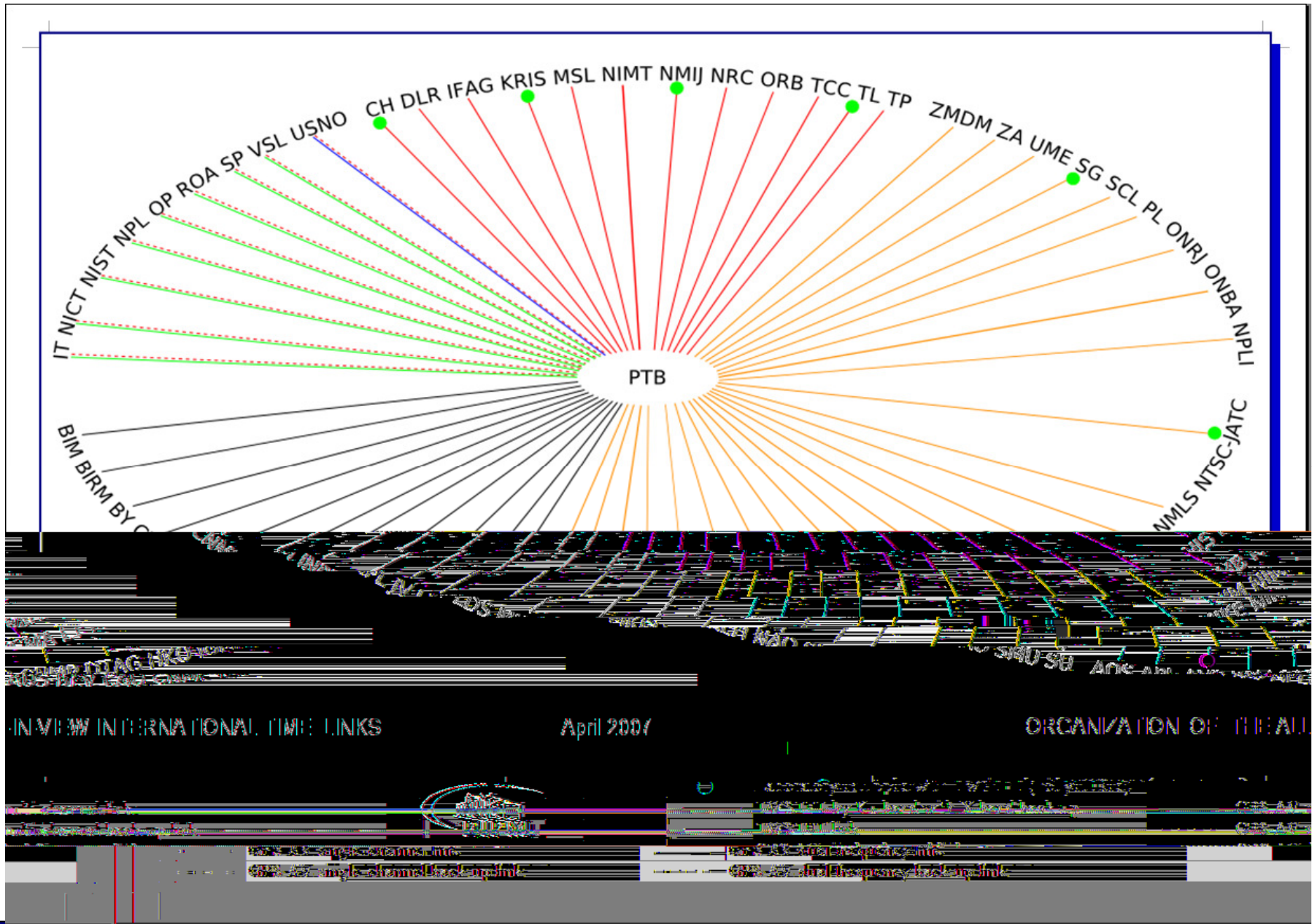
- **1884** - Adoption of a prime meridian Greenwich and of an associated time - universal time, based on the rotation of the Earth.
- **1948** - *International Astronomical Union* recommends the use of Universal Time (UT).
- **1968** - *13th General Conference of Weights and Measures* adopted a definition 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**

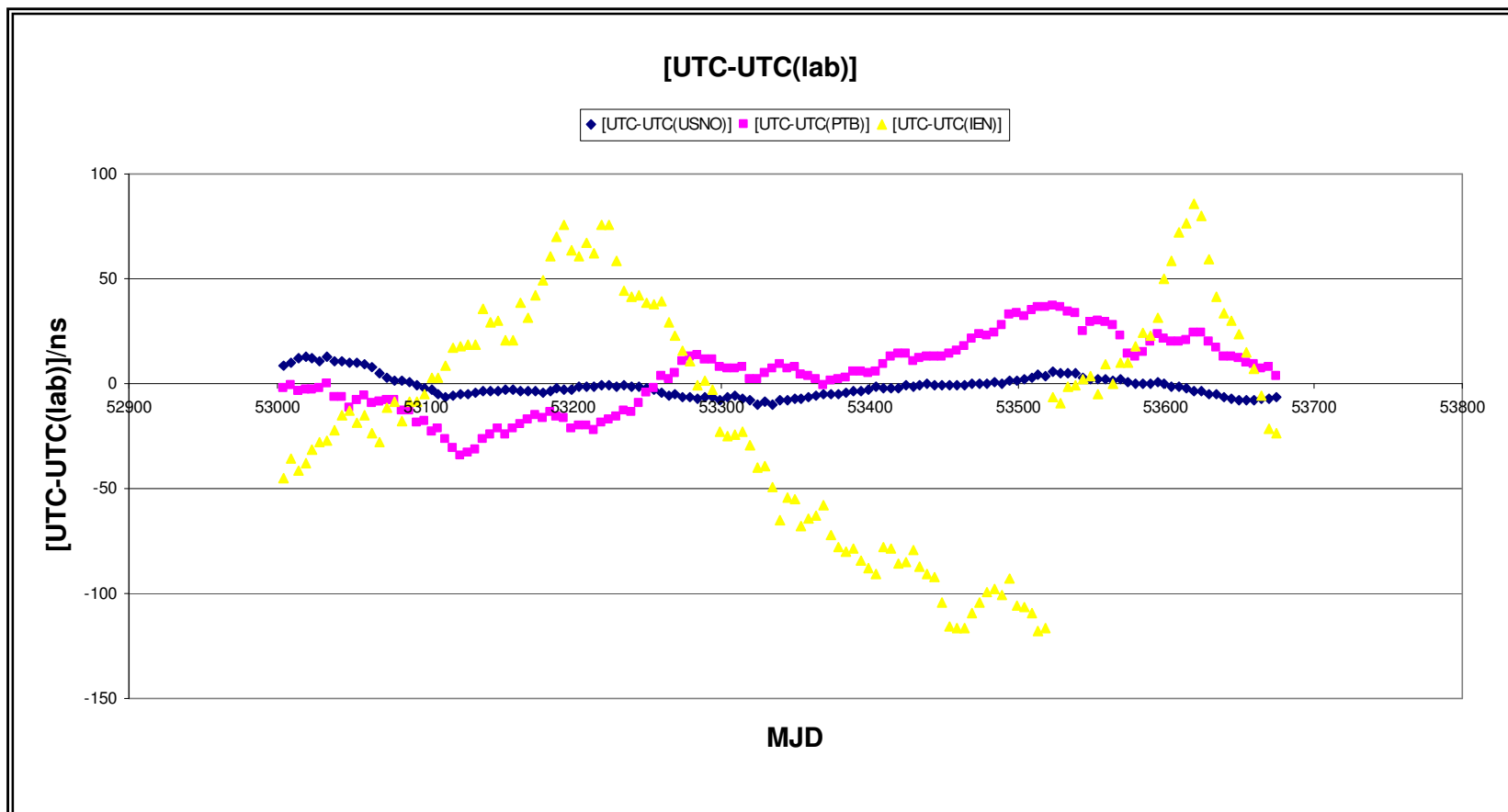
## Local realizations of UTC

- 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



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  |

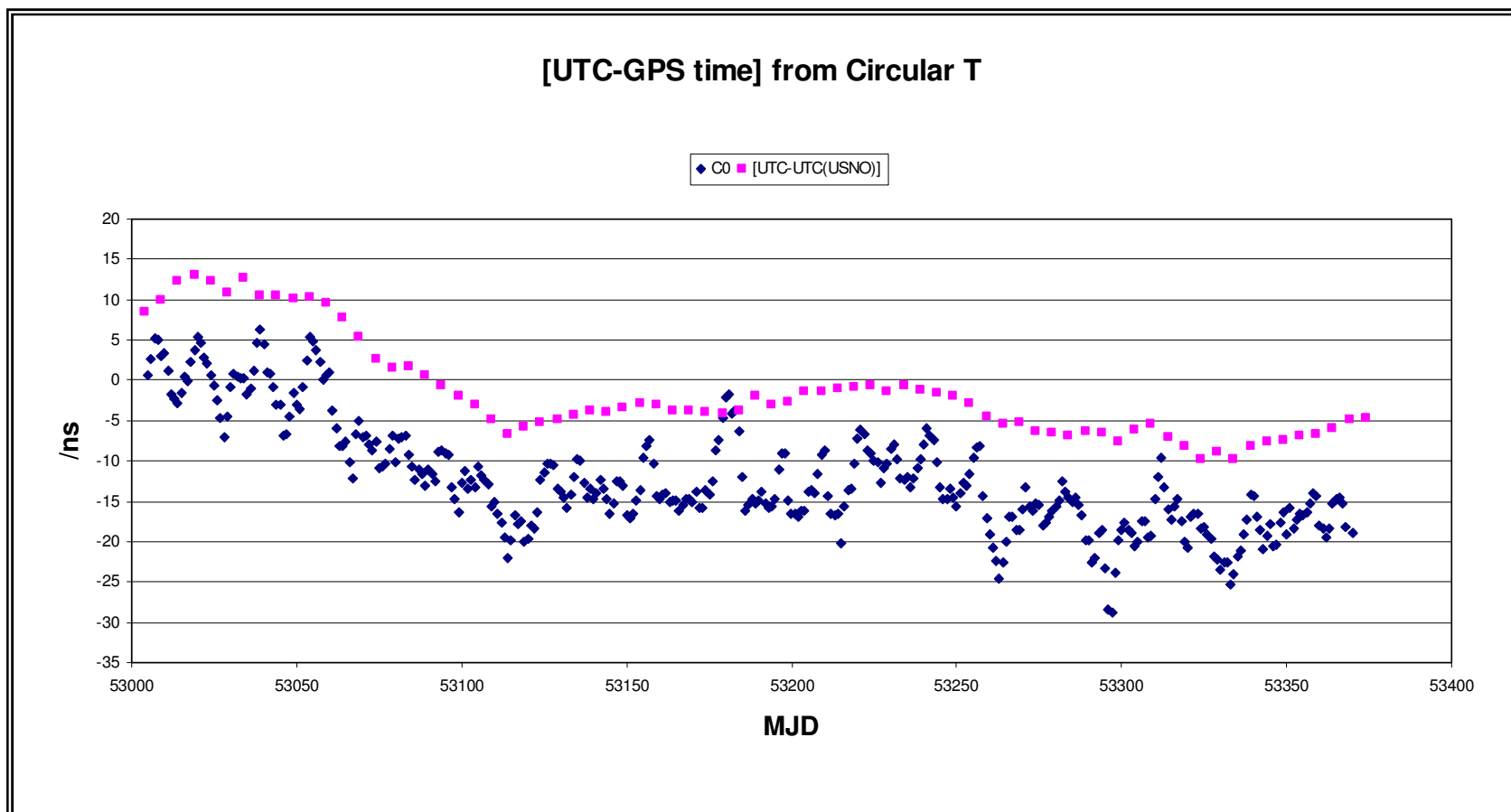


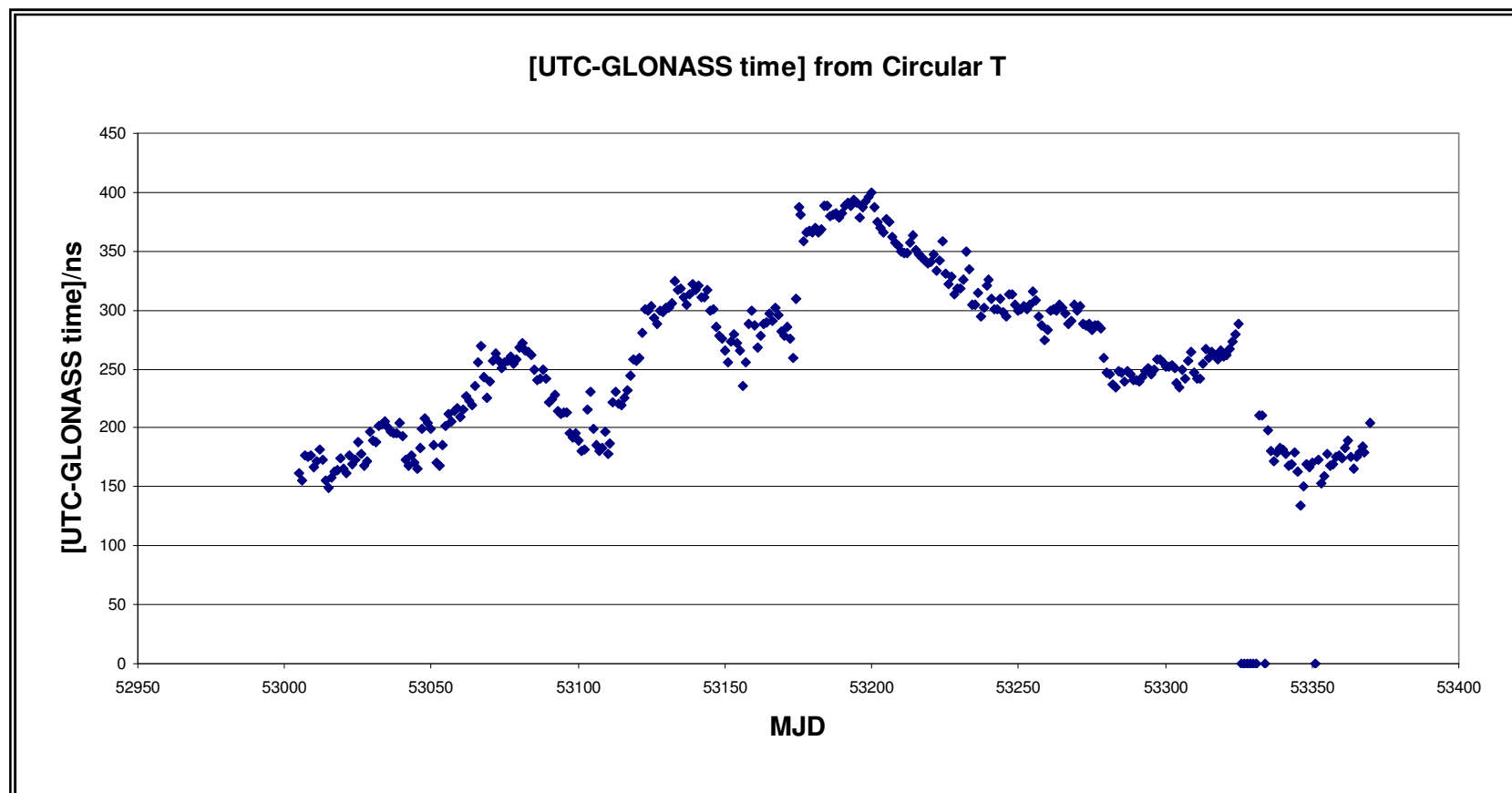


## System times

- 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
- ...







# System times

- GPS time: steered to UTC(USNO) modulo 1s

- ✓  $[TAI - \text{GPS time}] = 19 \text{ s} + C_0$
- ✓  $[\text{UTC} - \text{GPS time}] = -15 \text{ s} + C_0$
- ✓  $C_0 \leq 20 \text{ ns}$
- ✓ Tolerance is  $1 \mu\text{s}$

- GLONASS time: steered to UTC(SU) with leap second

- ✓  $[TAI - \text{GLONASS time}] = 34 \text{ s} + C_1$
- ✓  $[\text{UTC} - \text{GLONASS time}] = C_1$
- ✓  $C_1 \sim \text{some } 100 \text{ ns}$
- ✓ Tolerance is  $1 \text{ ms}$

- Galileo time: steered to a set of EU UTC(k); using GPS time seconds, GGTO

- ✓  $[TAI - \text{Galileo time}] = 19 \text{ s} + C_2$
- ✓  $[\text{UTC} - \text{Galileo time}] = -15 \text{ s} + C_2$
- ✓ Tolerance is  $50 \text{ ns}$

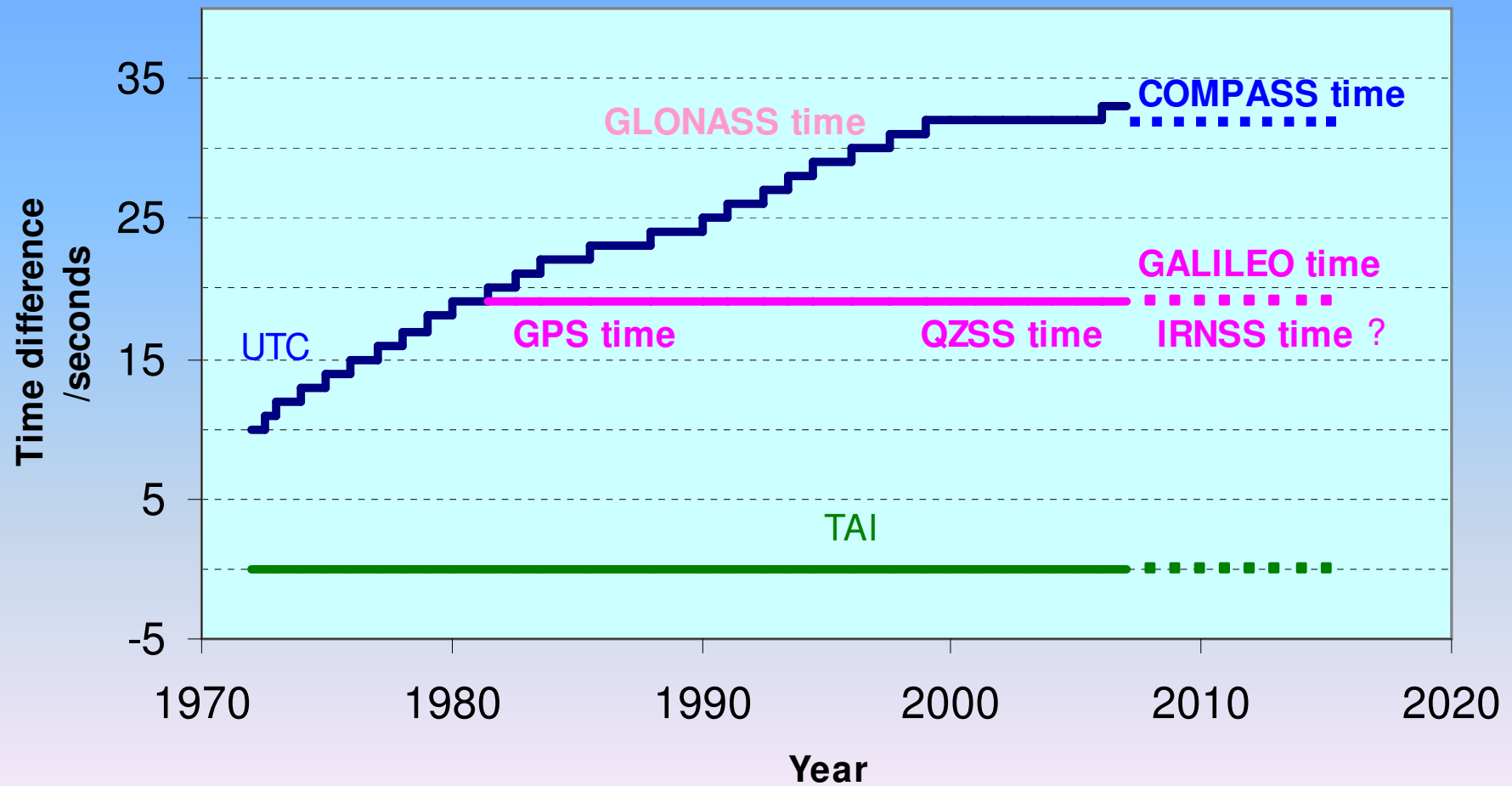
- COMPASS time: will be steered to set of Chinese UTC(k)

- ✓  $[TAI - \text{COMPASS time}] = 33 \text{ s} + C_3$
- ✓  $[\text{UTC} - \text{COMPASS time}] = -1 \text{ s} + C_3$
- ✓ Tolerance is  $100 \text{ ns}$





# [TAI - Time scale (i)]



# **ITU meeting on redefinition of UTC**

## **Geneva, 8-12 September 2009**

---

