



Bureau International des Poids et Mesures

# ***Use of international references for GNSS operations and applications***

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



Third Meeting of the ICG

8-12 December 2008 - Pasadena, California

# Outline

- Definition of international references
  - UTC
  - ITRS
- Use of international references in GNSS
  - GPS
  - GLONASS
  - Galileo
  - COMPASS/BeiDou
- Impact on interoperability

## Time unification – Definition of UTC

- 1971



International Astronomical Union

International Telecommunication Union



General Conference of Weights and Measures

- recommend the use of Coordinated Universal Time (UTC) based on TAI
  - Introduction of leap seconds.



## Coordinated Universal Time (UTC)

- UTC is computed monthly at the BIPM
- BIPM Circular T publishes [UTC-UTC(k)]
- TAI is based on the contribution of about 45 countries (about 350 clocks), it has only scientific applications, and is not represented by clocks
- Local realizations of UTC named UTC(k) are broadcast by time signals; they should approximate UTC better than 100 ns (recommended by CCTF)
- TAI and UTC differ in an integral number of seconds (33s today)
- UTC is the basis of legal times worldwide

## Geodetic references

- **Geocentric Terrestrial Reference System (GTRS)** as a “System of geocentric space-time coordinates within the framework of General Relativity, co-rotating with the Earth and related to Geocentric Celestial Reference System by a spatial rotation which takes into account the Earth Orientation Parameters”, in agreement with the IAU resolution B1.3 2000

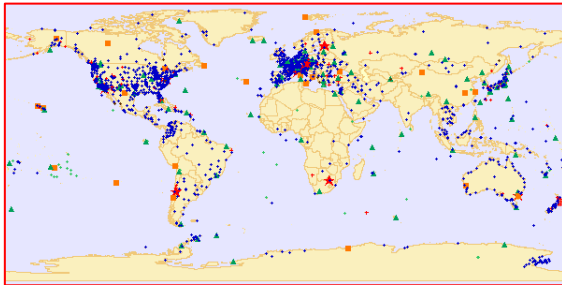


- **International Terrestrial Reference System (ITRS)** as the specific GTRS for which the orientation is operationally maintained in continuity with past international agreements, endorsed by the IUGG



## Realizations of ITRS

- International Terrestrial Reference Frame (ITRF), realized by the services of International Association of Geodesy (IAG)



- World Geocentric System 84 (WGS84) – aligned to ITRF at a few cm level (US), *used by GPS*
- PZ-90.02 (2007) (Russia), agrees with ITRF better than 40 cm, *used by GLONASS*
- Galileo Terrestrial Reference Frame (GTRF) – aligned to ITRF at a few cm level
- China Geodetic System (CGS`2000), agrees with ITRF to ...  
???, *used by COMPASS*
- Regional networks (densification of ITRF)

# GNSS

- GNSS times
  - ✓ System times
  - ✓ Constructed from an atomic clock ensemble
  - ✓ Used for internal system synchronization
  - ✓ Continue (desirable)
  - ✓ Metrologic quality (not requested)
  - ✓ Steered to a reference time scale
- GPS time
- GLONASS time
- Galileo time (future)
- COMPASS time (future)

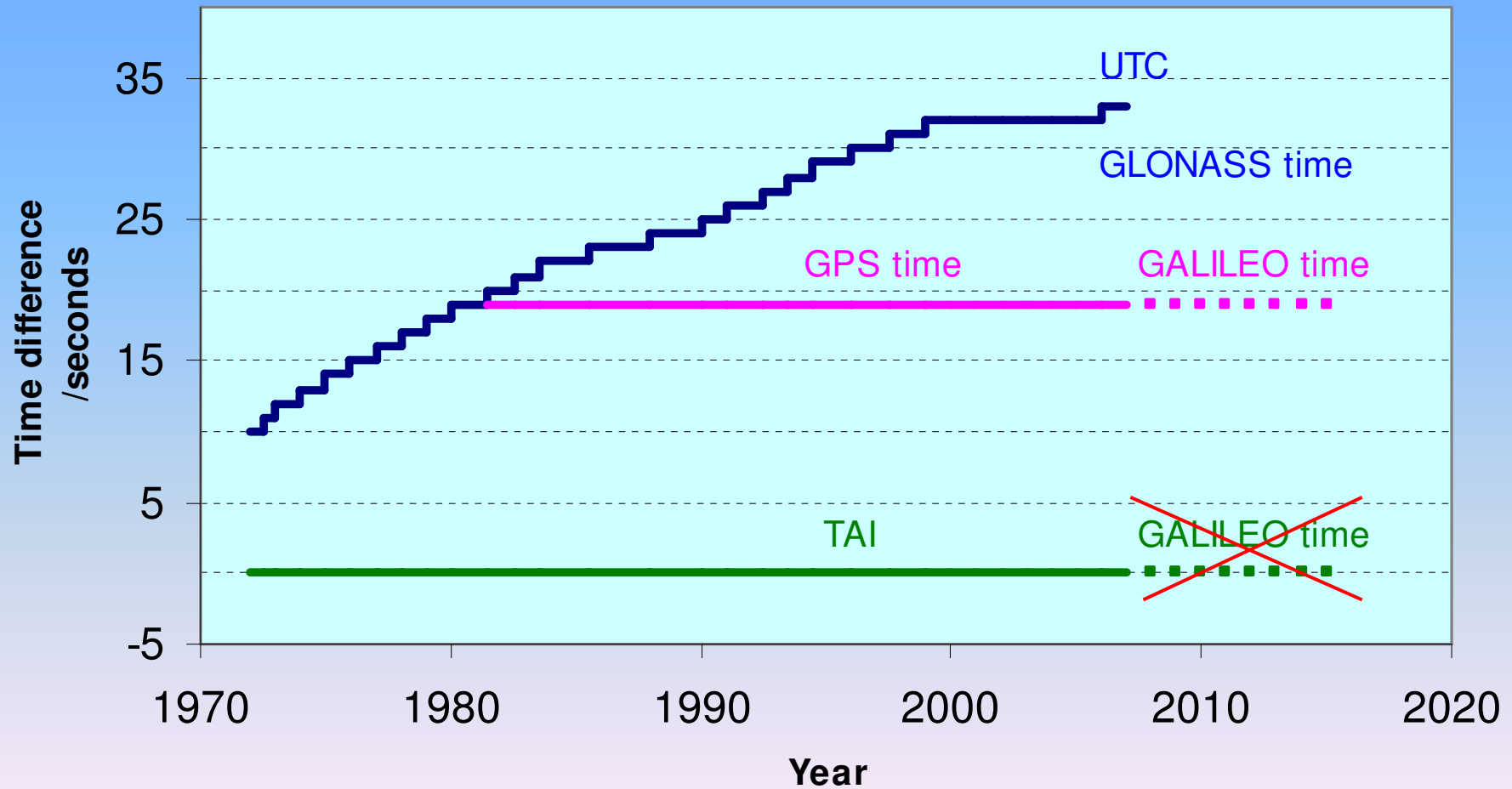
# System times

- **GPS time: steered to UTC(USNO) modulo 1s**
  - ✓  $[\text{TAI} - \text{GPS time}] = 19 \text{ s} + C_0$
  - ✓  $[\text{UTC} - \text{GPS time}] = -14 \text{ s} + C_0$
  - ✓  $C_0 \leq 20 \text{ ns}$
  - ✓ Tolerance is  $1 \mu\text{s}$
- **GLONASS time: steered to UTC(SU) with leap second**
  - ✓  $[\text{TAI} - \text{GLONASS time}] = 33 \text{ s} + C_1$
  - ✓  $[\text{UTC} - \text{GLONASS time}] = C_1$
  - ✓  $C_1 \sim \text{some } 100 \text{ ns}$
  - ✓ Tolerance is  $1 \text{ ms}$
- **Galileo time: steered to a set of EU UTC(k); using GPS time seconds, GGTO**
  - ✓  $[\text{TAI} - \text{Galileo time}] = 19 \text{ s} + C_2$
  - ✓  $[\text{UTC} - \text{Galileo time}] = -14 \text{ s} + C_2$
  - ✓ Tolerance is  $50 \text{ ns}$
- **COMPASS time: steered to ....???**
  - ✓  $[\text{TAI} - \text{COMPASS time}] = ? + C_3$
  - ✓  $[\text{UTC} - \text{COMPASS time}] = ? + C_3$
  - ✓ Tolerance is  $100 \text{ ns}$

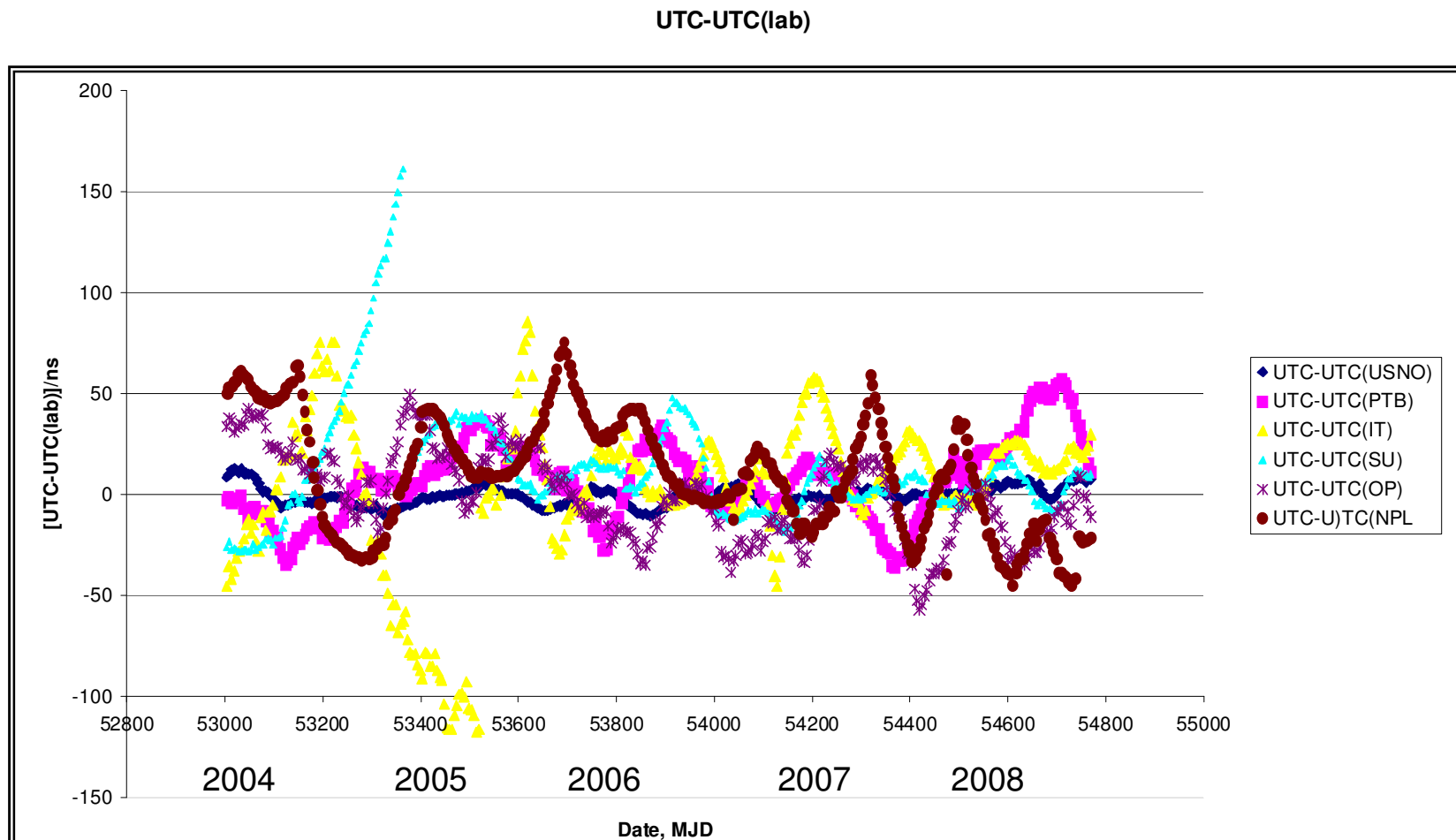




# [TAI - Time scale (i)]

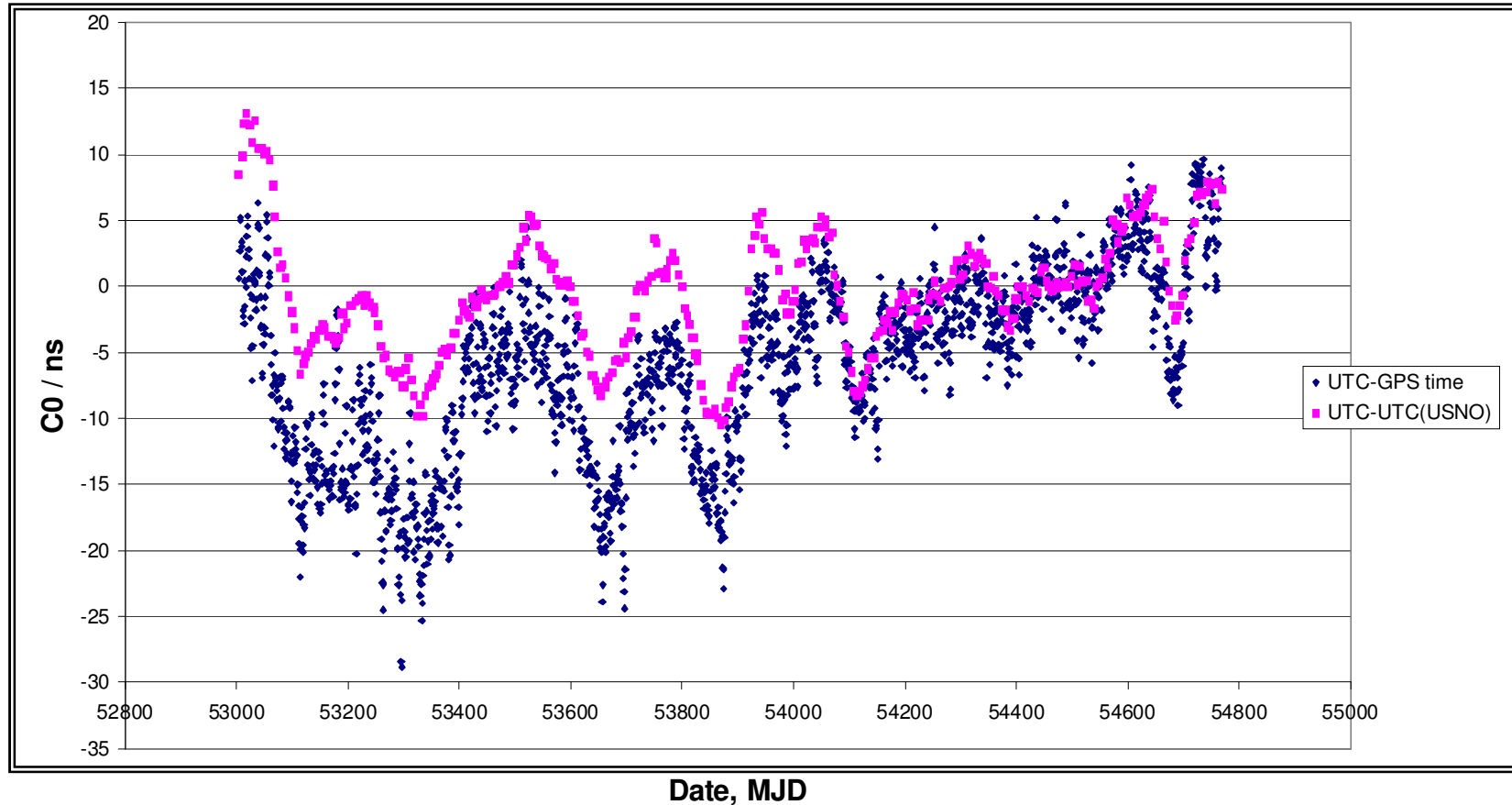


# Relationship between UTC and local realizations UTC(k)



# Relationship between UTC and GPS time

[UTC - GPS time] from BIPM Circular T



## Multiple GNSS interoperable

- **Unique terrestrial reference system**
  - ITRS, recommended by IAU, IUGG for application in space and Earth sciences
  - Access to ITRS is possible through its different realizations, ITRF (primary), WGS84, PZ-90, GTRF, CGS'2000, plus regional densifications
- **Unique reference time scale for steering GNSS times**
  - Independent from any GNSS time
  - Reliable, enjoying the highest metrological quality (frequency stability and accuracy)
  - UTC, as constructed by the BIPM on the basis of national metrology institutes contribution that maintain real-time approximations UTC(k)
  - Unique reference should be continuous

## Conclusion

- All GNSS should provide UTC timing service
- Each GNSS system should align their navigation time scale to UTC
- Elimination of leap second would be helpful to GNSS
- All GNSS systems should align to a common geodetic reference frame (ITRF)
- The two new proposed task forces in WGD will address these issues

