Use of international references for GNSS operations and applications

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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

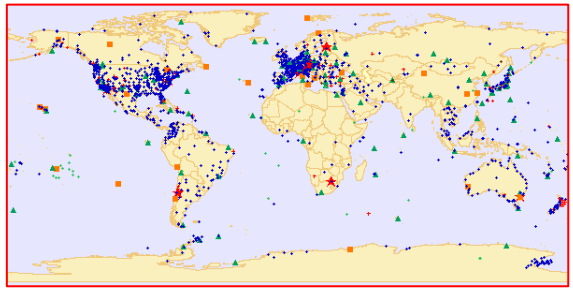
Geodetic references

- 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

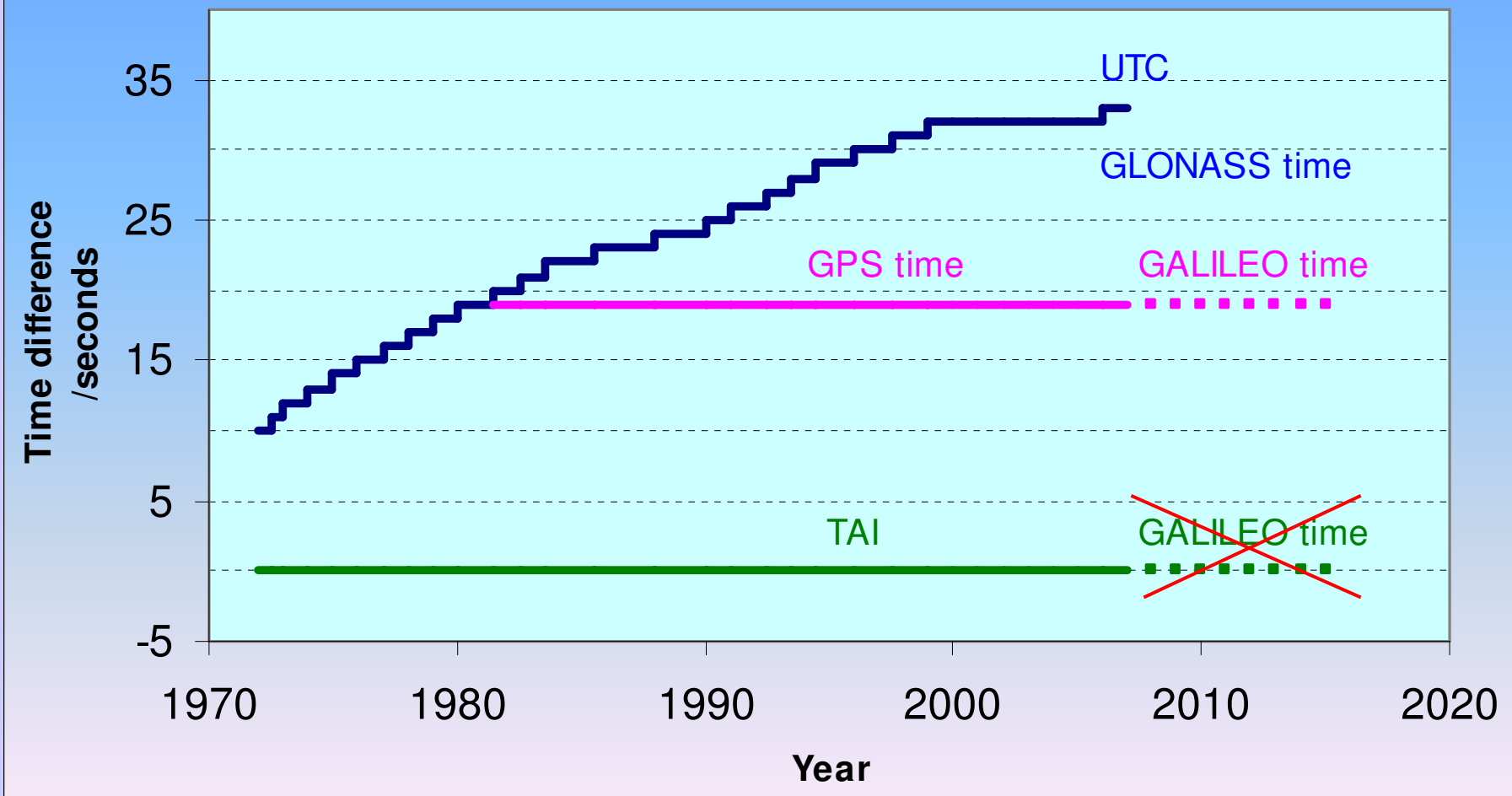
- GNSS times
  - ✓ System times
  - ✓ Constructed from an atomic clock ensemble
  - ✓ Used for internal system synchronization
  - ✓ Continue (desirable)
  - ✓ Metrologic quality (not requested)
  - ✓ Steered to a reference time scale

- GPS time
- GLONASS time
- Galileo time (future)
- COMPASS time (future)

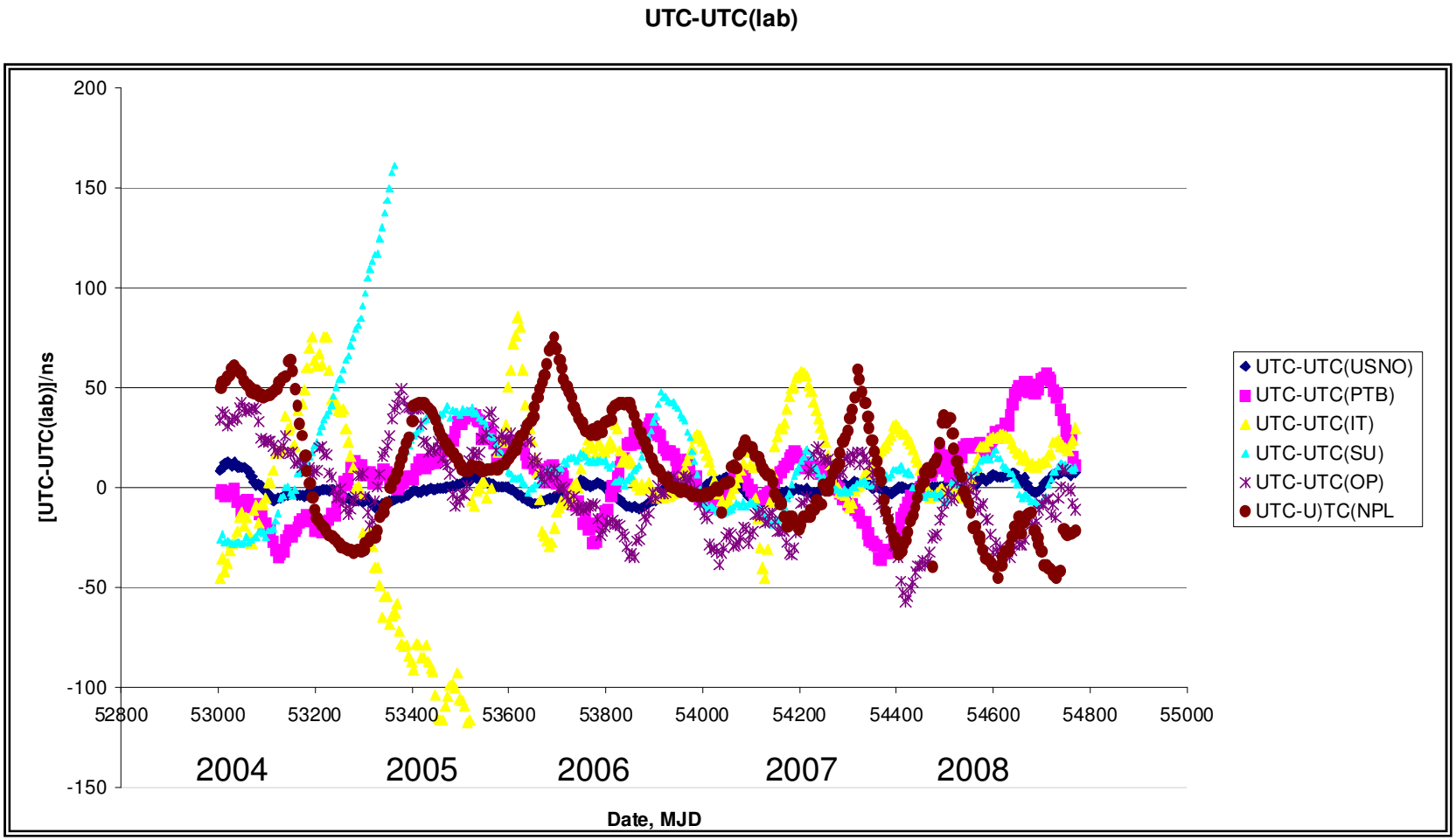
System times

- GPS time: steered to UTC(USNO) modulo 1s
  - ✓ [TAI – GPS time] = 19 s + C_0
  - ✓ [UTC -GPS time] = -14 s + C_0
  - ✓ $C_0 \leq 20$ ns
  - ✓ Tolerance is 1 μs
- GLONASS time: steered to UTC(SU) with leap second
  - ✓ [TAI – GLONASS time] = 33 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] = -14 s + C_2
  - ✓ Tolerance is 50 ns
- COMPASS time: steered to ….???
  - ✓ [TAI –COMPASS time] = ? + C_3
  - ✓ [UTC -COMPASS time] = ? + C_3
  - ✓ Tolerance is 100 ns

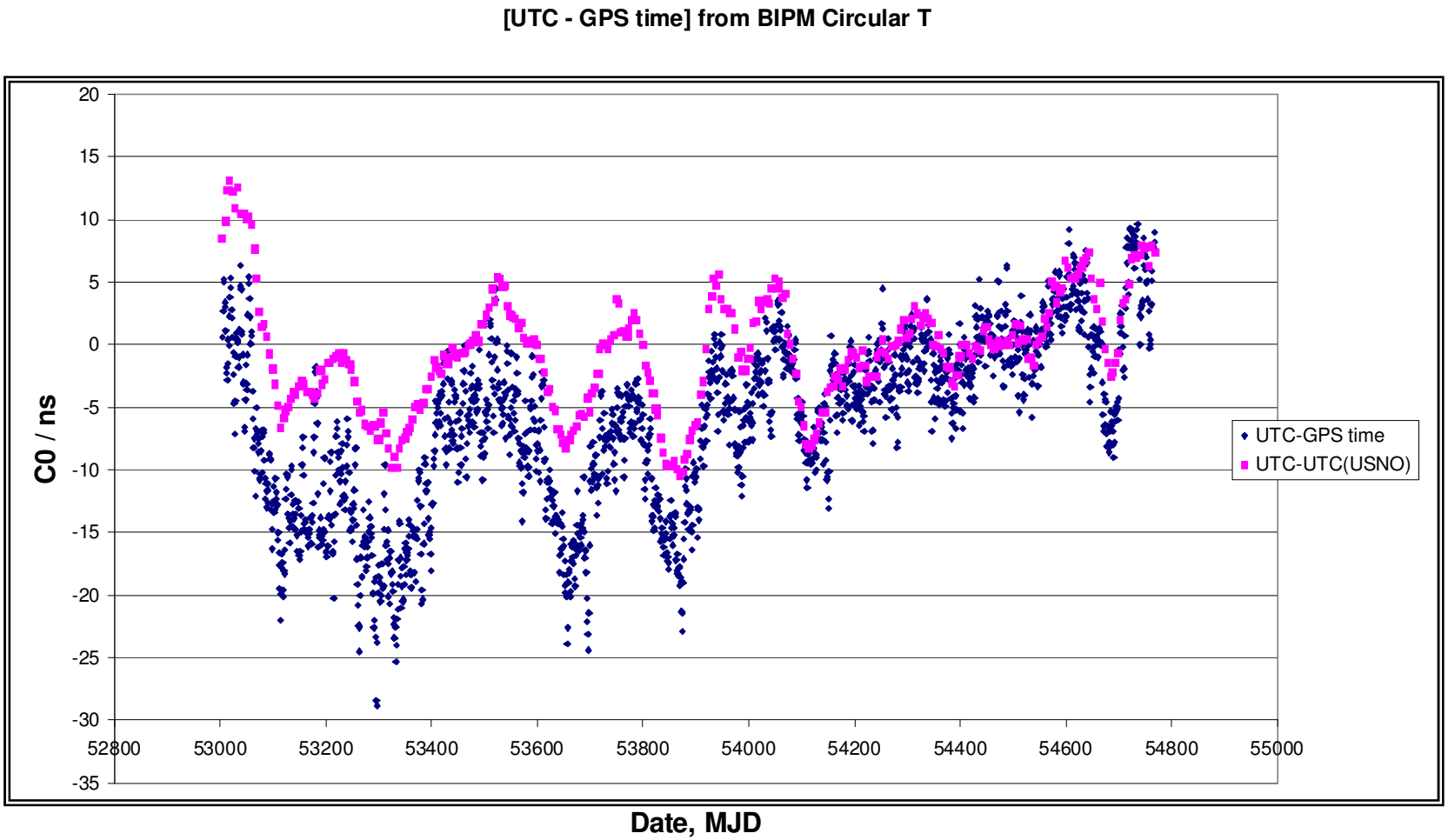
[*TAI - Time scale (i)*]



Relationship between UTC and local realizations UTC(k)



Relationship between UTC and GPS time



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