Impact of GGTO determination and accuracy on positioning and timing

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Outline

- ICG Proposed unifying the XYTO dissemination

  Rather than broadcasting all the GNSSTi-GNSSTk:
  Use a common reference and broadcast GNSSTi-REF [1]

- What can be this reference ?
  - A new time scale (e.g. an average of GNSS Time scales)
  - UTC_{pred} in the broadcast message “GNSST-UTC(brdc)”
- Which is the needed XYTO accuracy for PNT?
  - Should the XYTO be determined or taken from nav message?
  - Impact of XYTO errors on the position error
- Conclusions

[1] Twelfth Meeting of the International Committee on Global Navigation Satellite Systems (ICG), Kyoto, Japan, 3 - 7 December 2017

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References for XYTO

Two possible references were proposed in [2]:

- CASE 1: an average of the GNSS time scales of the different systems (that we call *$GNSST_{mean}$*)

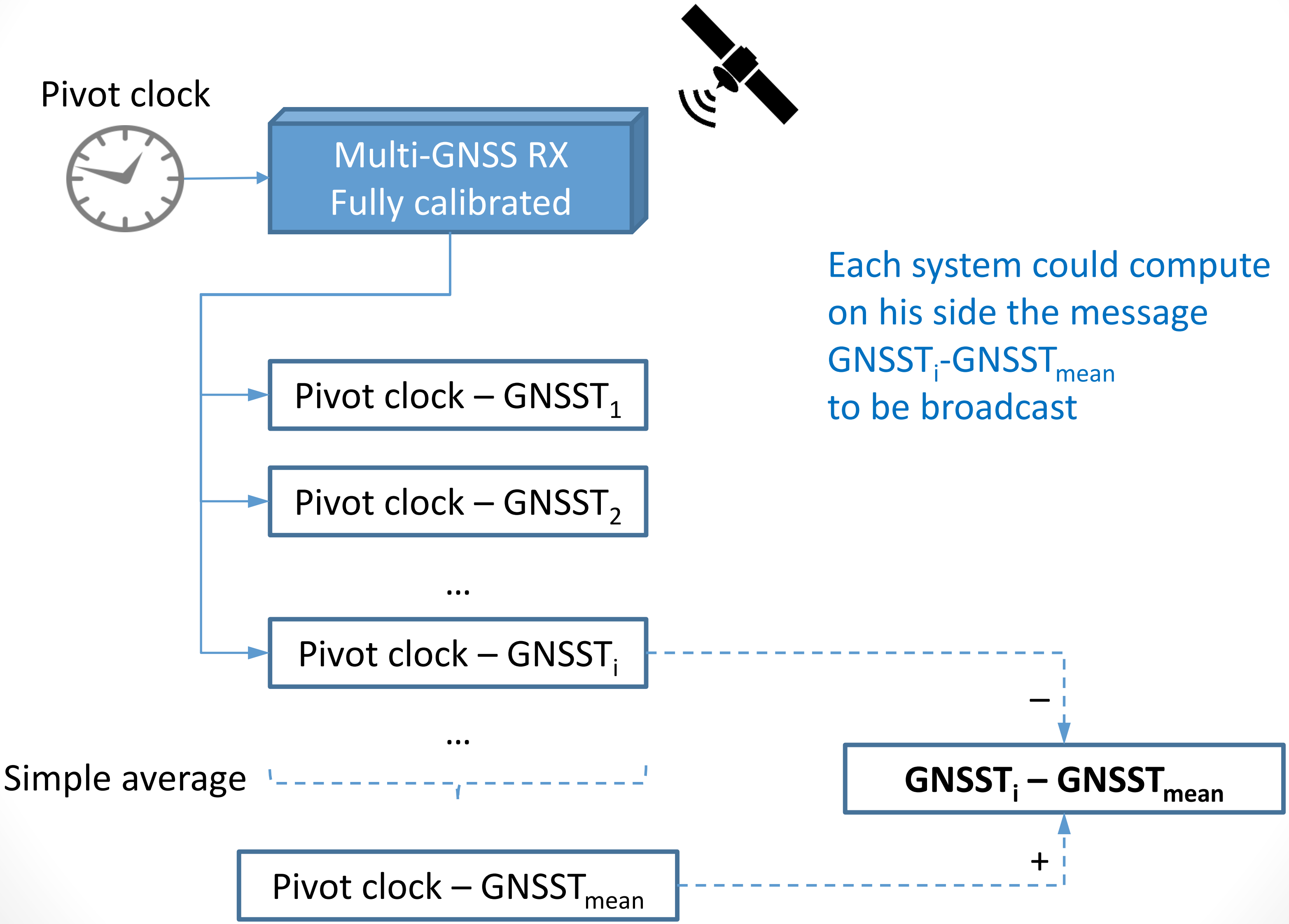
  →Each system would provide GNSST-GNSSTmean

- CASE 2: UTC_{SiS} by using directly the GNSST-UTC predictions broadcast by the different systems

  →No additional message should be broadcast by the systems

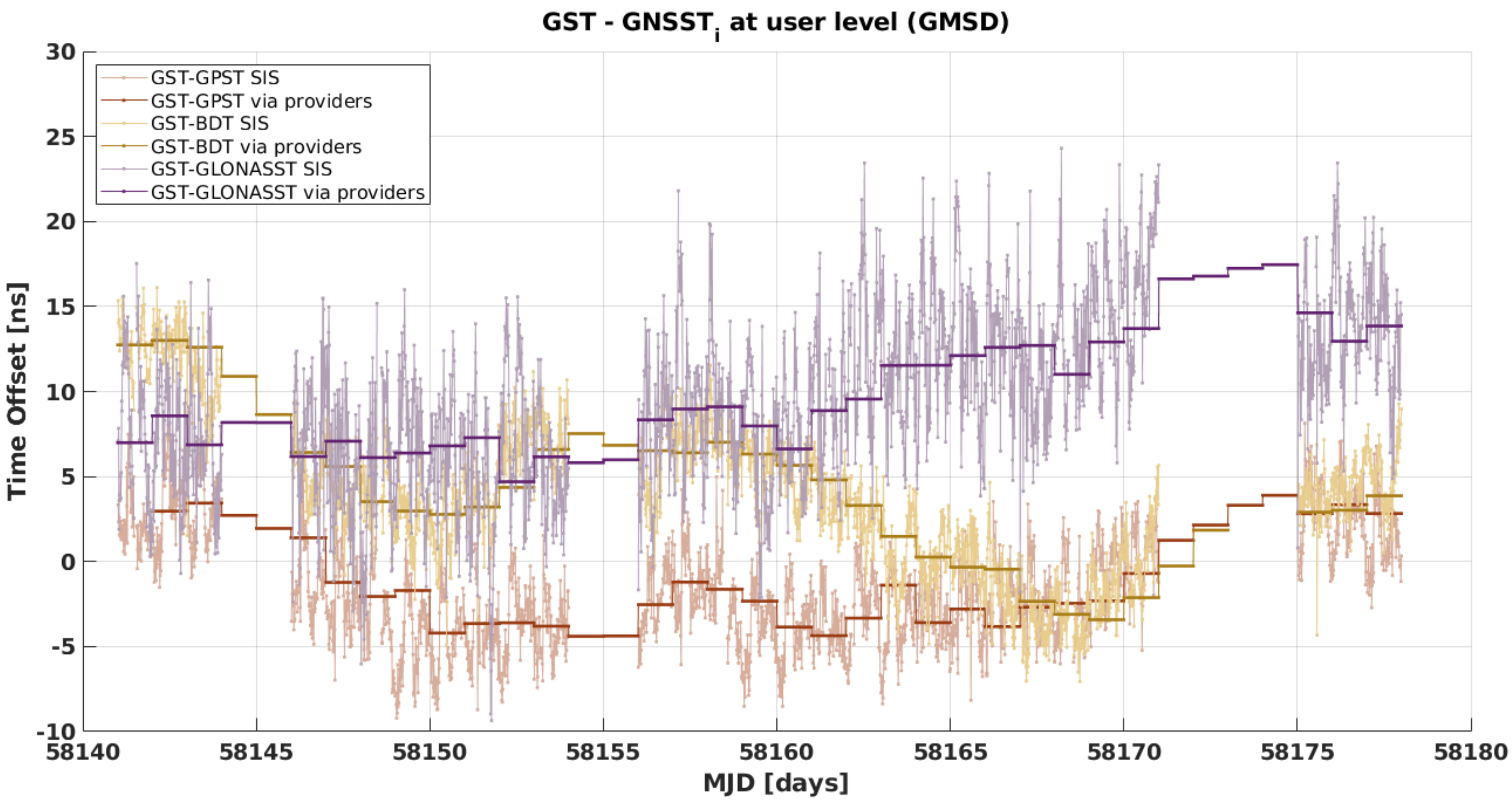
[2] Galileo and GNSS Time Offset, G. Signorile, I. Sesia, T.T. Thai, P. Defraigne, P. Tavella, EFTF 2018, April Turin, Italy

CASE 1: broadcast $GNSST_i$-$GNSST_{mean}$



Each system could compute on his side the message $GNSST_i$-$GNSST_{mean}$ to be broadcast

Efficiency of GXTO as broadcast against $GNSS_{mean}$



CASE 1: conclusion

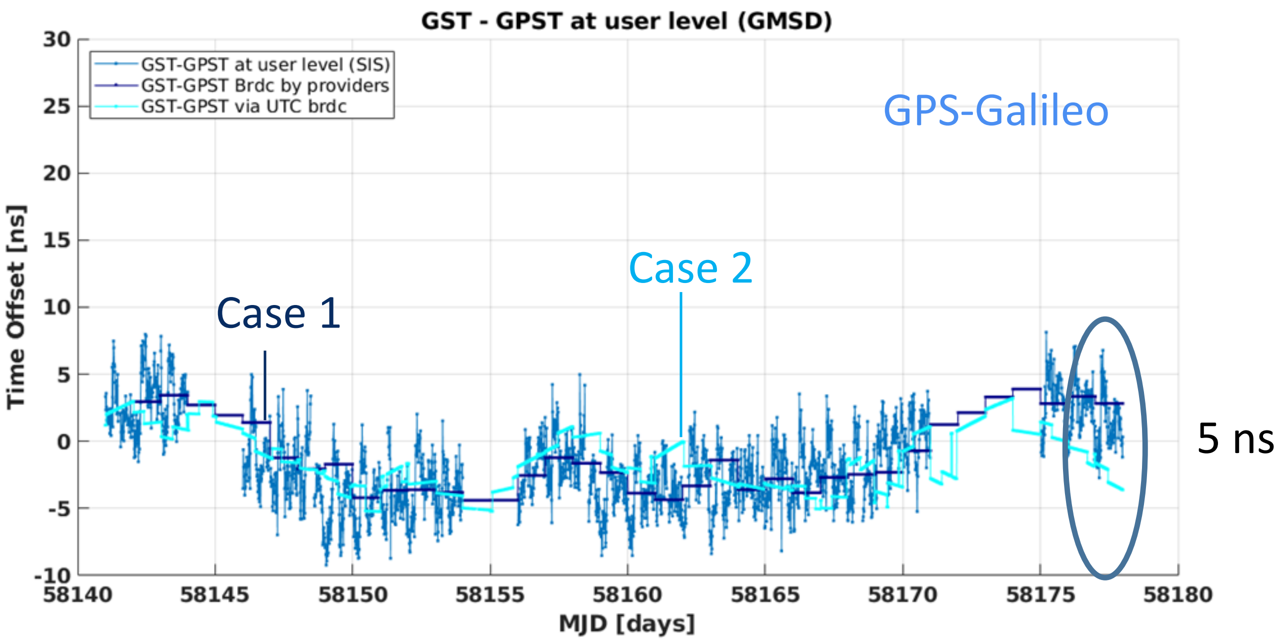
- $GNSST_i$-$GNSST_{mean}$ provides an accurate (2-3 ns) access to XYTO for the user (if the receivers used to computed are accurately calibrated)

- The different visibility of satellites is not affecting the computation of $GNSST_{mean}$ in the different continents

CASE 2: XYTO via broadcast UTC_{pred}-GNSST

$$XYTO = [GNSST_x - \cancel{UTCbrdc}_{x}] - [GNSST_y - \cancel{UTCbrdc}_{y}]$$

Difference can be several ns (or more)



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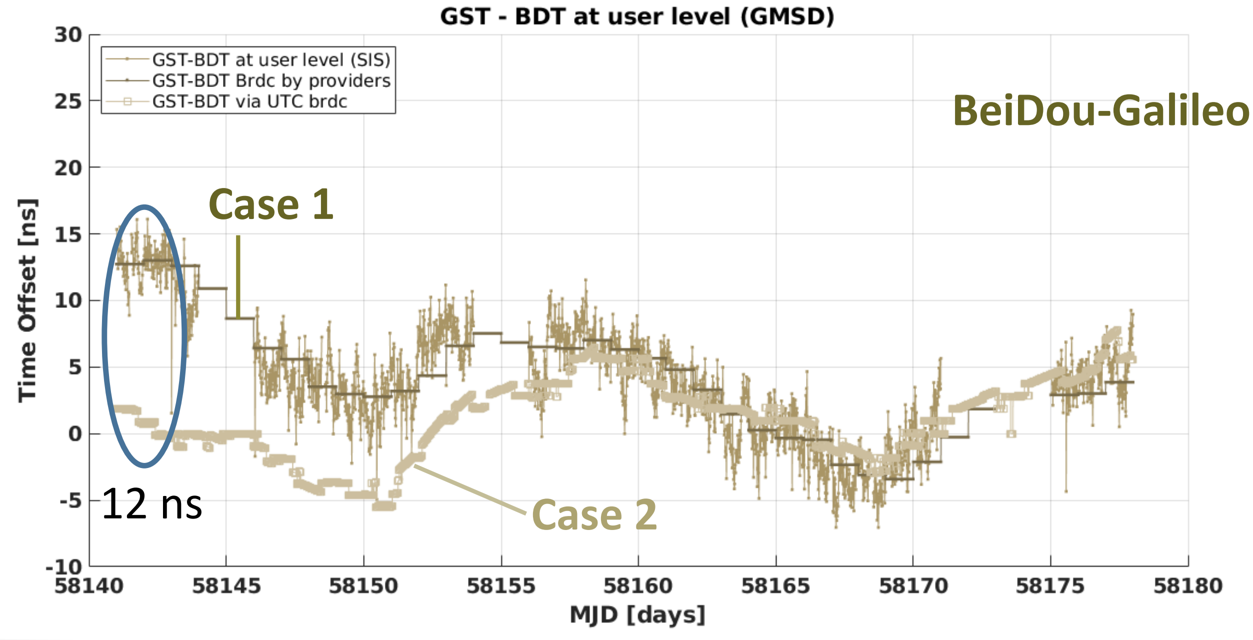

CGSIC, Miami, September 16, 2019 P. Defraigne

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Which is the needed XYTO accuracy?

- GGTO = GPST-GST

But in the receiver :

GPST® = GPST + HW delays (signal used)

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GGTO = GPST®-GST®-HWD(GPS)+HWD(Galileo)

- **Single Frequency users** :
  (L1) is used by both systems,
  we can consider that the HWD is close (difference < 3ns)

BUT SF users need TGD and BGD, while there is a bias of about 2 ns in the broadcast BGD → difference between the true GGTO and the GGTO(user) is within 5 ns.

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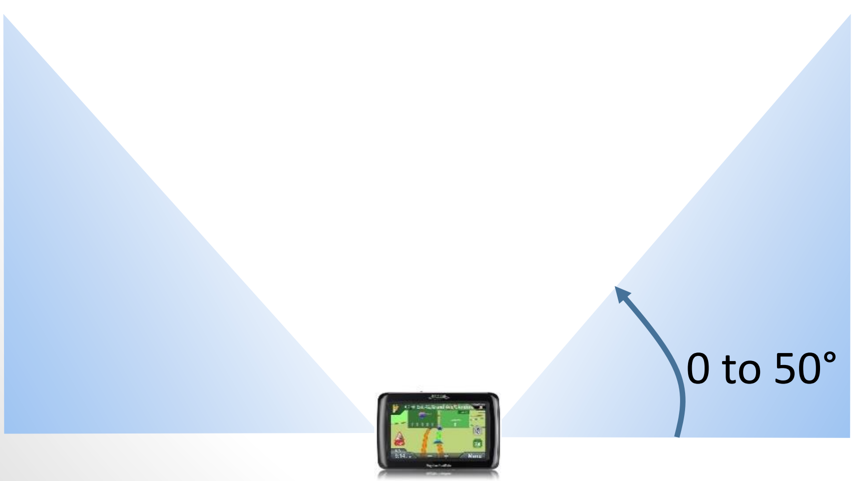
- **Dual-Frequency users**:
  - (L1 L5) for both GPS and Galileo → HW probably similar
- - (L1 L2) is used by GPS, (L1 L5) by Galileo,
  HW delays of the IF combination can be up to 10 ns.

→ Even if an accurate GGTO is broadcast, it can be far from the user GGTO which includes HW biases.

Impact of XYTO accuracy on positioning

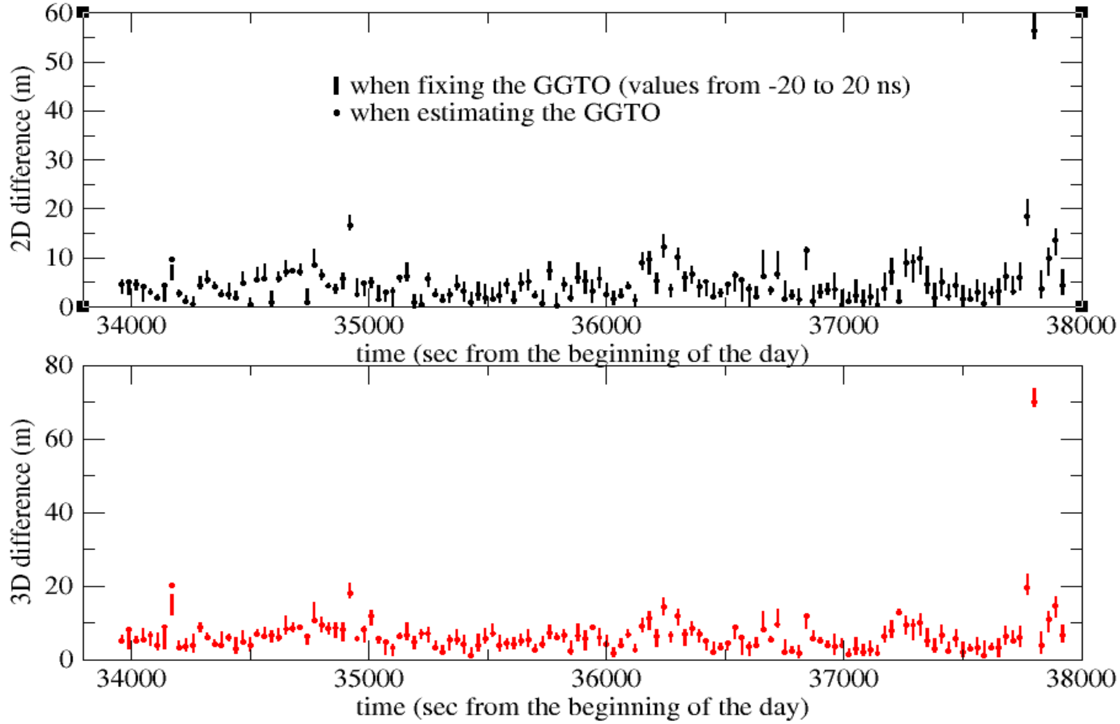
- Use GPS+Galileo data and GGTO
- Smartphone data / High precision receiver
- Single-Frequency user, Klobuchar for the iono correction
- Compare position obtained when
  - estimating the GGTO
  - using brdc GGTO, with errors between 0 and 20 ns
- Simulate canyons using different elevation cutoffs
- Each epoch, determine position with available satellites



Using Smartphone data

2-frequency Broadcom chip

Using 1 hour of data – good visibility (roof) - no elevation cutoff



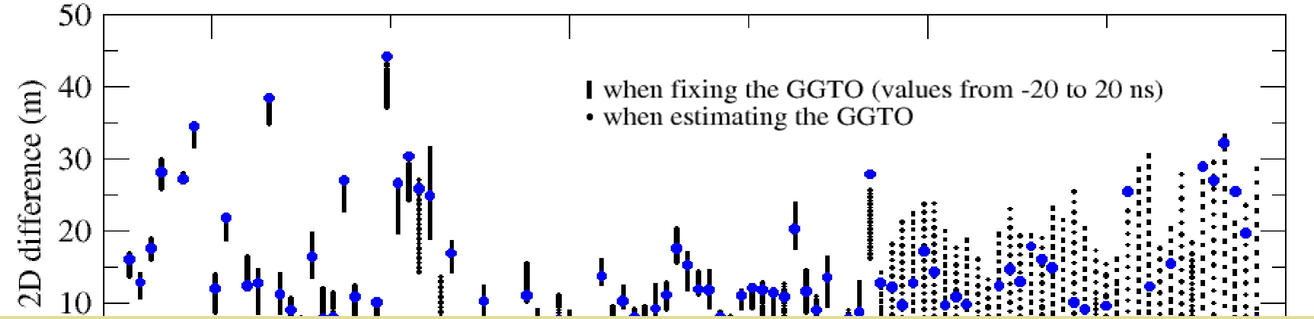
noisy data

→ no significant changes if using broadcast GGTO or estimating GGTO

→ the impact of an error (even up to 20 ns) on the GGTO is not significant for a mass market receiver

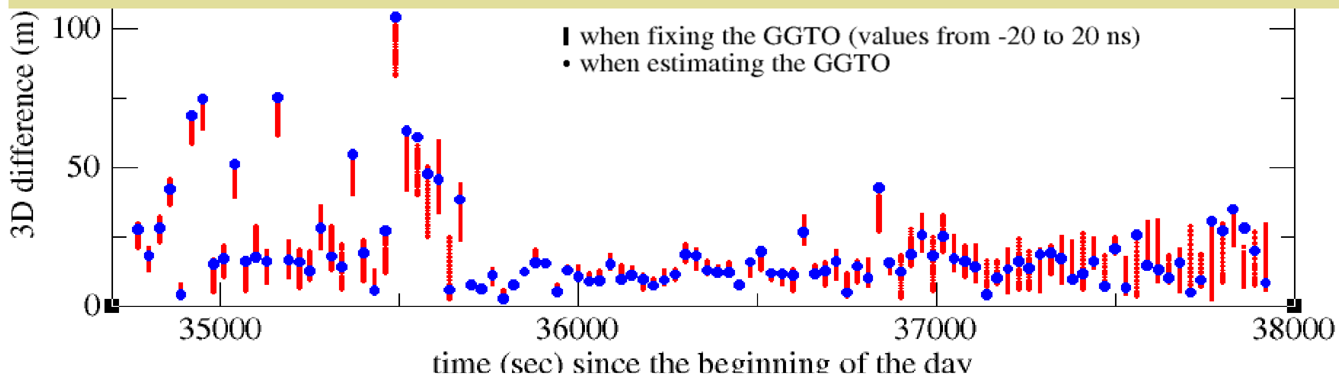
Using Smartphone data

Using 1 hour of data – elevation cutoff 40°

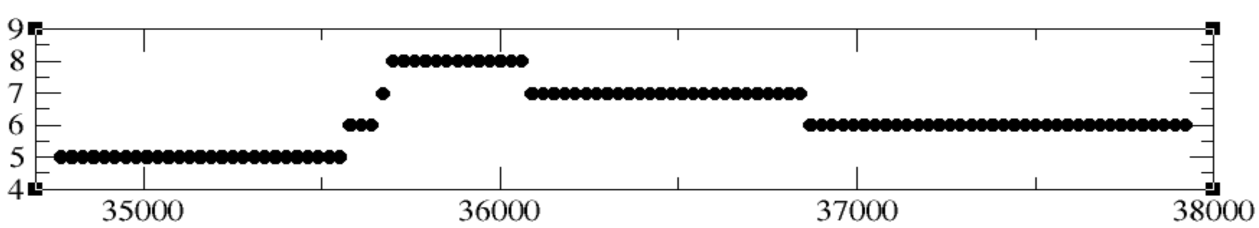


noisy data

→ in poor visibility (5-6 satellites), using GGTO is better than estimating it.



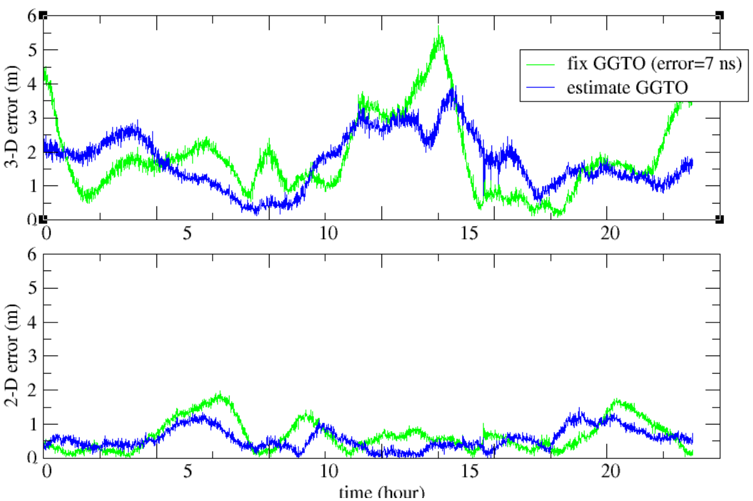
Number of observed satellites



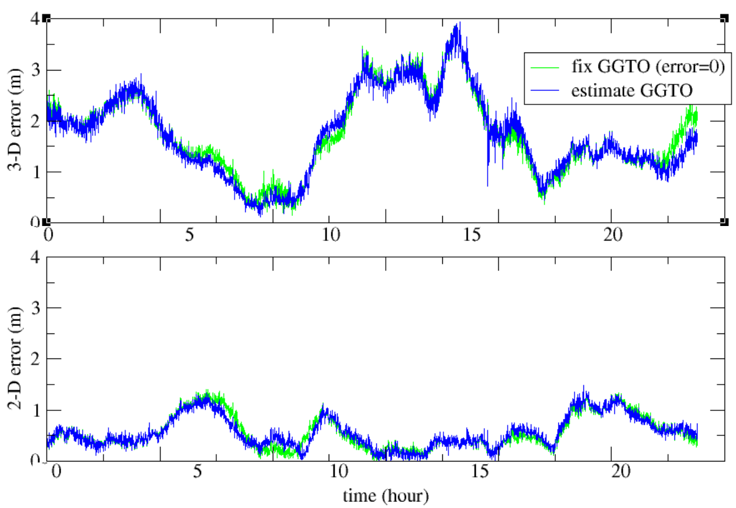
High precision receiver (BRUX)

No elevation cutoff

GGTO “error” 7 ns

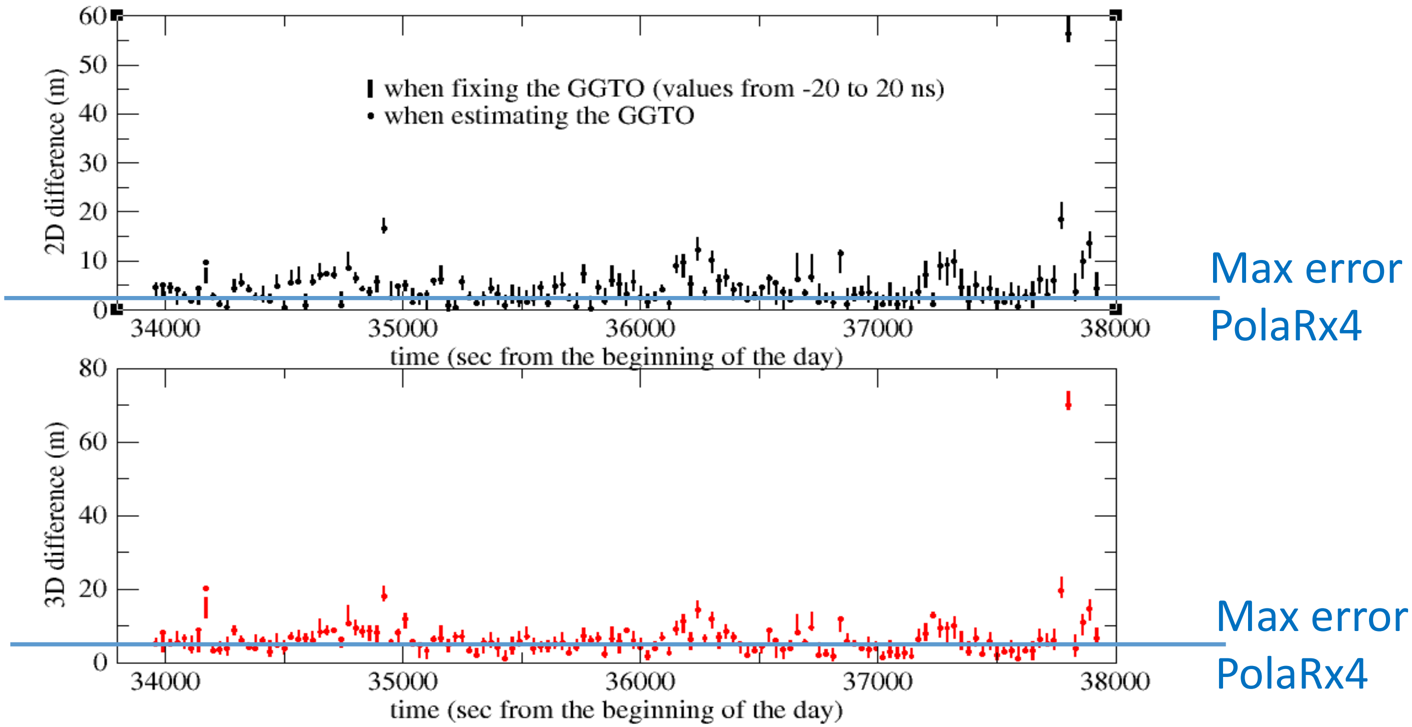


Correct GGTO (for the receiver)



Comparison with Smartphone data

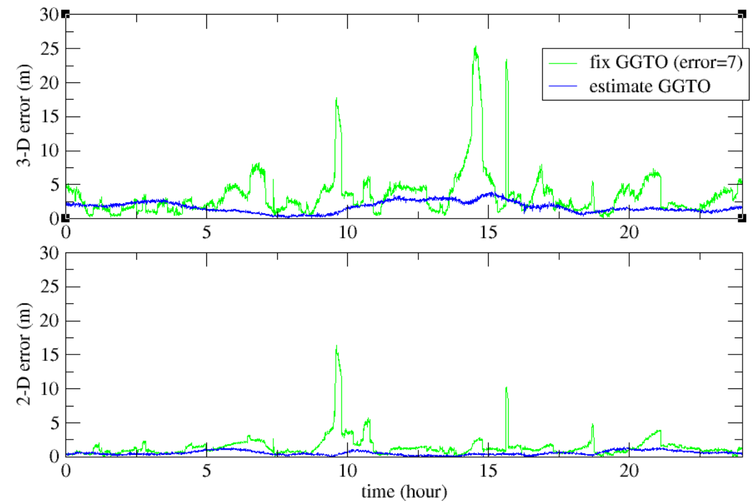
Using 1 hour of data – no elevation cutoff



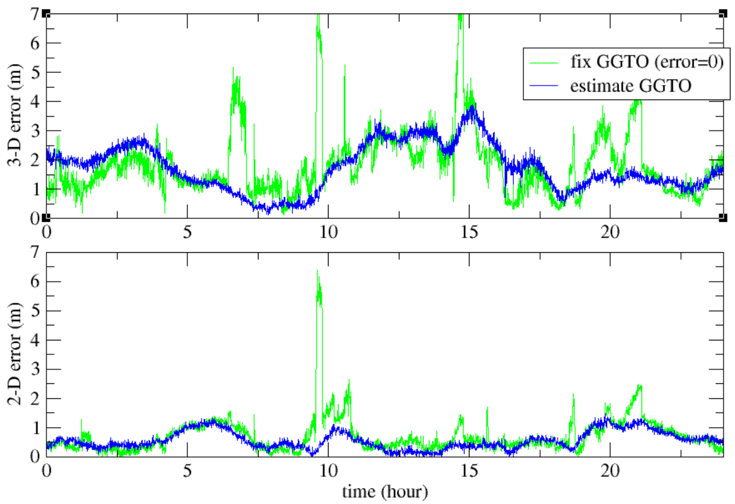
High precision receiver (BRUX)

Cutoff 30°

GGTO error 7 ns



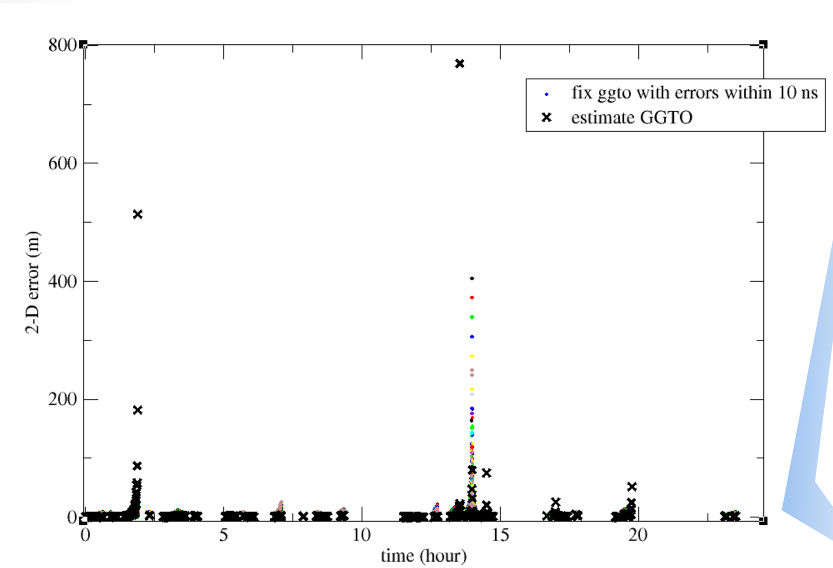
Correct GGTO (for the receiver)

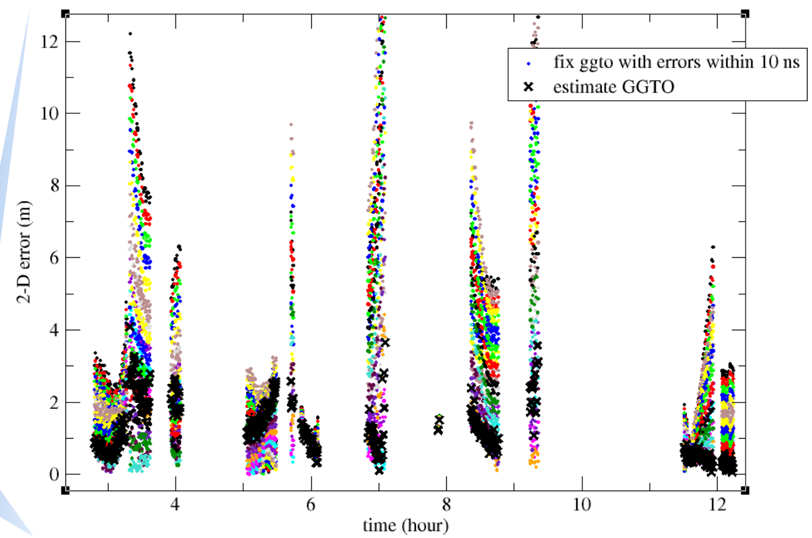


Note : the “correct GGTO” depends on the errors in brdc satellite clocks → more sensitive when there are less satellites

When only 5 satellites available

(here in a cutoff at 50°)





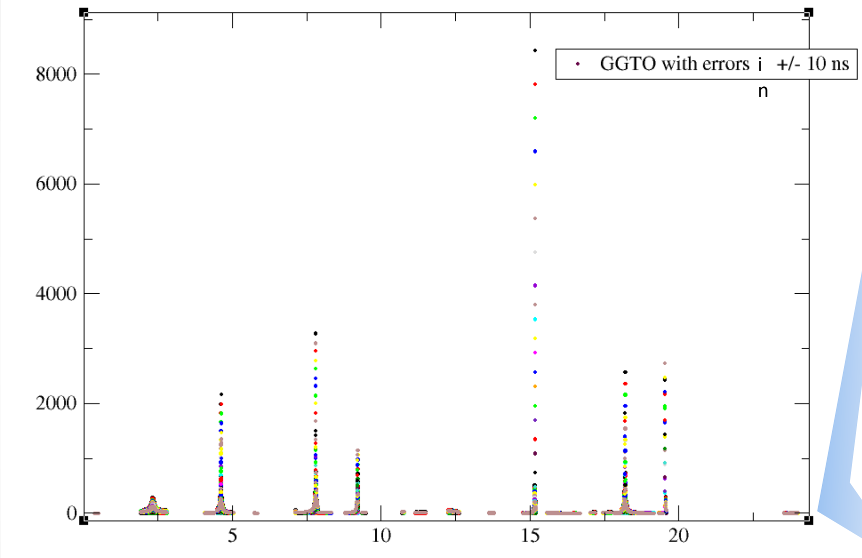
- Estimate GGTO is generally better,
- furthermore, not always the same 'fixed' GGTO gives the best solution.
- Conclusion :
  determine GGTO as soon as possible, even with 5 satellites

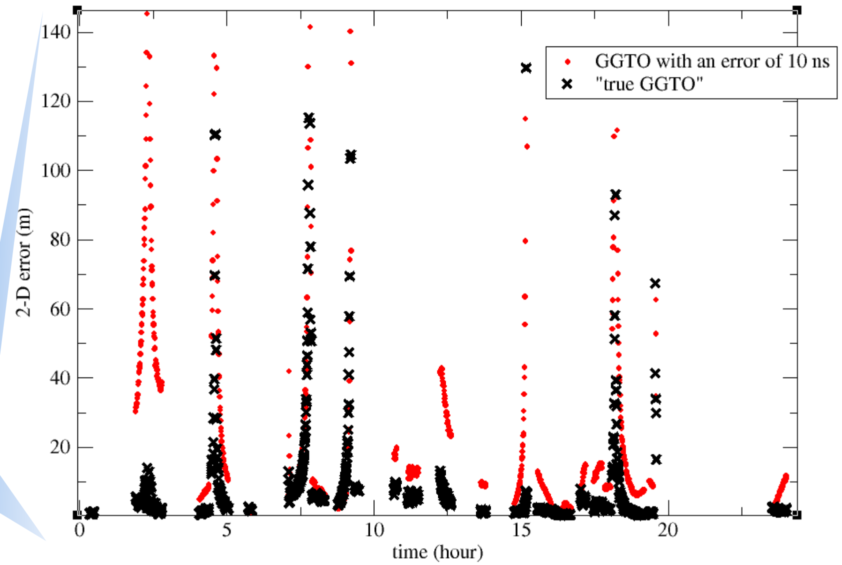
When only 4 satellites available

→ GGTO mandatory

Results here for cutoff 50°

At all these epochs, we would not have a solution with only one constellation





- With 4 satellites like in a canyon, having a "correct GGTO" improves the position accuracy
- Even with a "correct GGTO", the position error can be large (>200m), due to geometry + few satellites
- An error of 10 ns induces horizontal error > 100 m for only 6.5% of time while 2.0% with a "correct GGTO"

When only 4 satellites are available: How getting the “correct GGTO”?

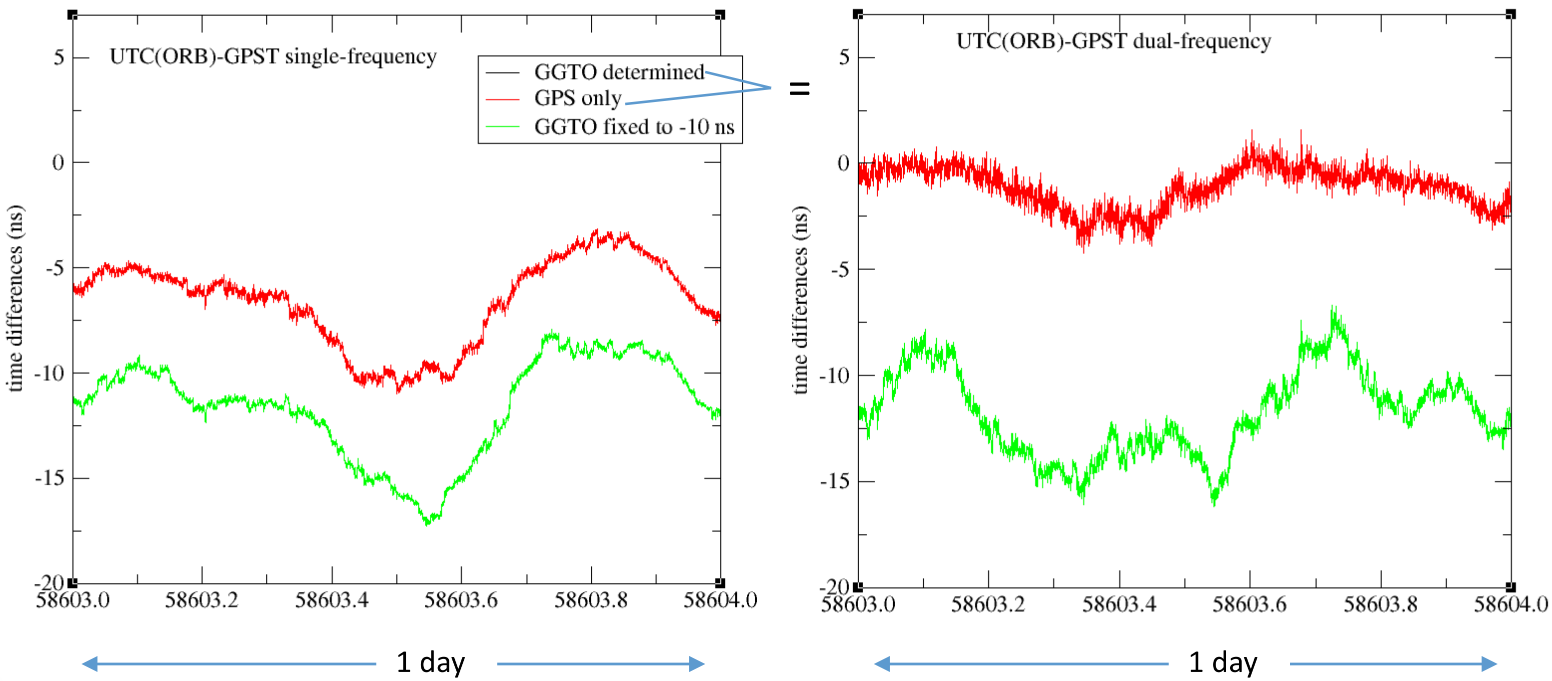
Correct GGTO = GPST-GST-HW(receiver)

- From Nav message → ok if inter-system HW biases are small (a few ns).
- From a previous estimation (averaged to get rid of the noise) : uncertainty depends on the time elapsed since the last estimation in view of
  - the stability of the GNSST
  - the stability of the HW delay

For Timing

Data from a high precision receiver connected to a H-maser

Usually : good visibility and considers a fix position



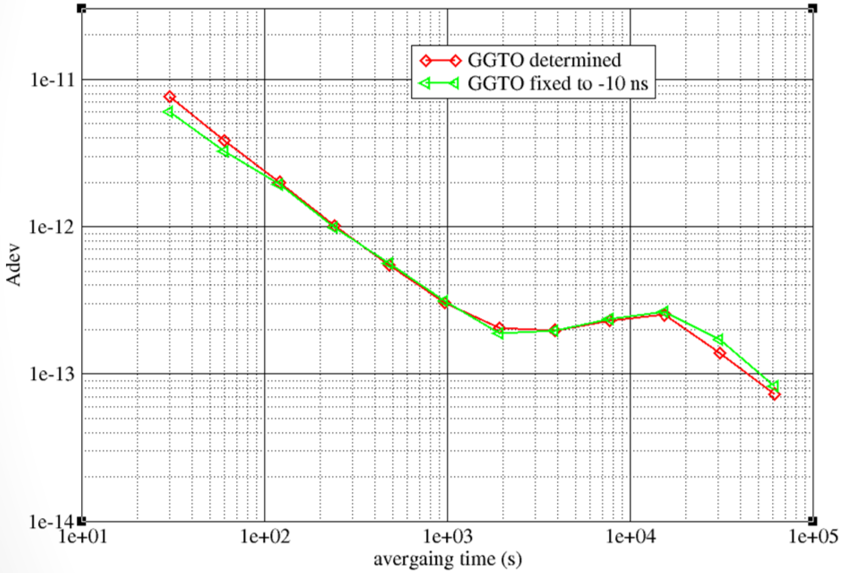
Fixing a GGTO induces a distortion of the solution due to the variable ratio of satellites GPS/Galileo

For Timing

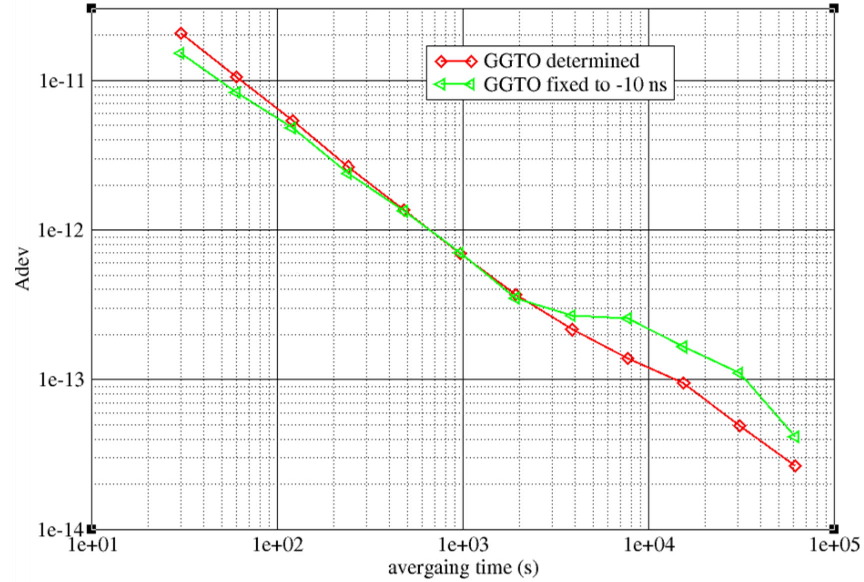
Usually : good visibility and considers a fix position

UTC(ORB)-GPST from GPS+Galileo

Single-frequency



Dual-frequency



While the use of a fix GGTO improves the short term stability, it also degrades the long term stability.

Conclusion (1/2)

- A correct XYTO at receiver level can be different from the broadcast value due to inter-system hardware delays (can be large especially for different frequencies)
- Broadcast values of XYTO should be used only when the number of satellites available prevents its correct determination:

This number of satellites depends on the measurement noise.
- For a high precision receiver, XYTO should be determined even with 5 available satellites.
- For a smartphone, from our preliminary results, XYTO is useful when only 5 or 6 satellites are available
More tests are foreseen, to get a better insight.

- When not enough satellites are available to determine a YXTO, a fixed value should be used, either from a previous estimation by the receiver or from the navigation message

Conclusion (2/2)

- So, if an uncertainty of 10 ns is accepted on the XYTO, then using GNSST-UTC_{pred} broadcast in the nav message will be sufficient, as soon as the UTC_{pred} coincide within 10 ns
- There is no need to develop a new time scale as common reference to broadcast a unique GNSSTi-REF for each system