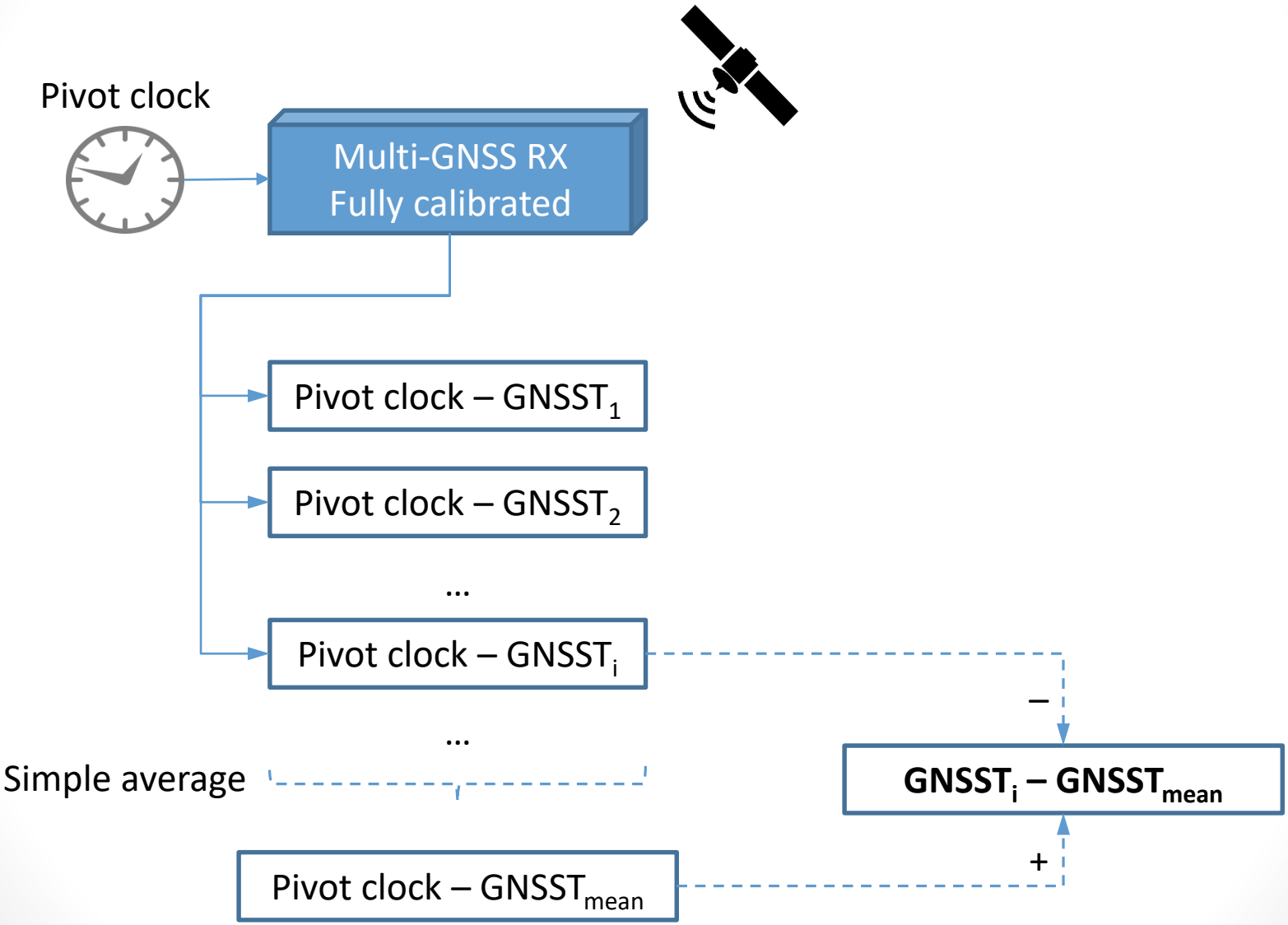
Different ways of estimating the GGTO, and their impact on the position accuracy

P. Defraigne , Royal Observatory of Belgium
I. Sesia, T.T. Thai, G. Signorile, INRIM
P. Tavella, BIPM

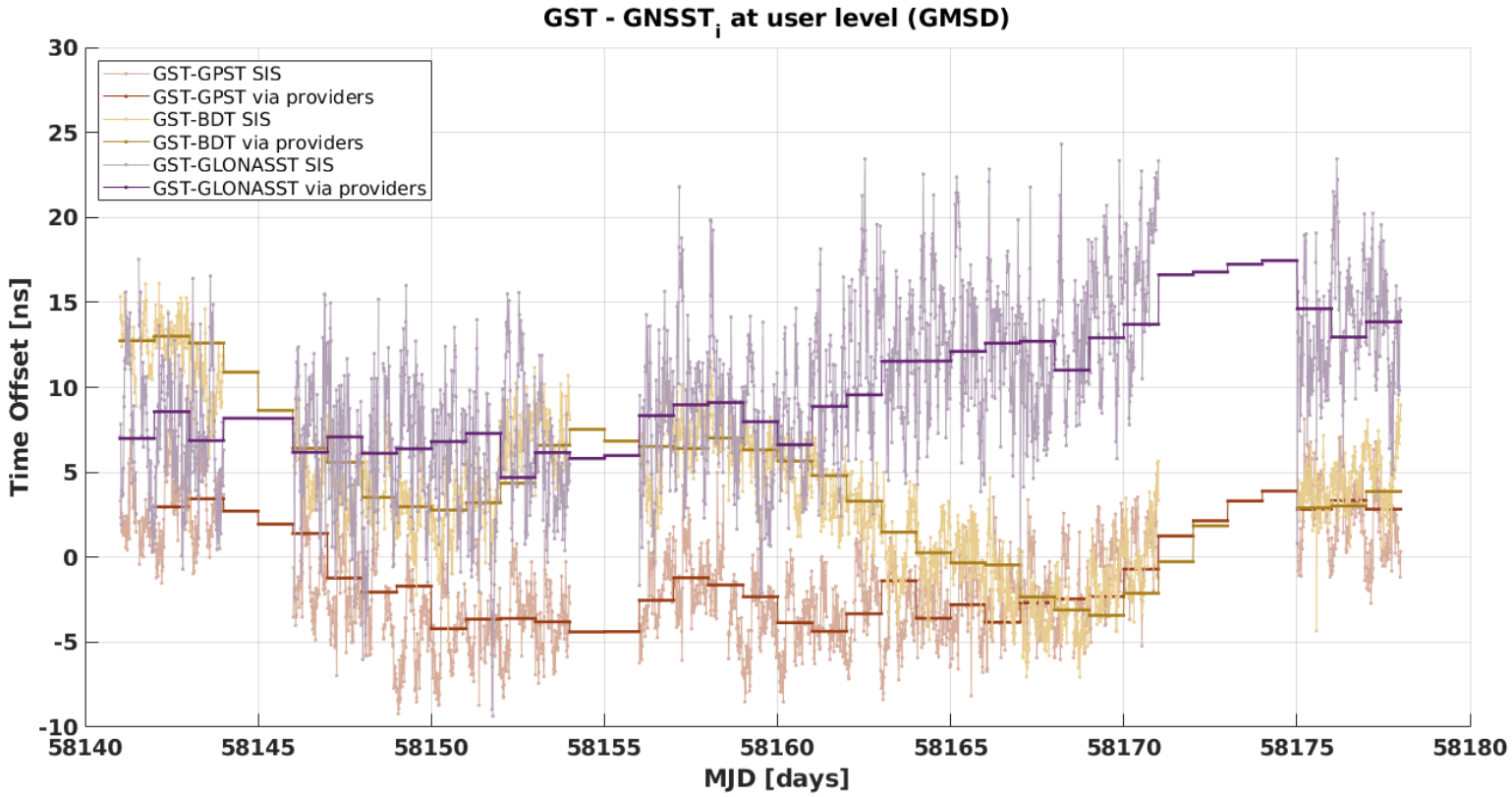
Outline

- Proposed ways of unifying the XYTO dissemination and their performances
  - Using an average of GNSS Time scales as reference
  - Using the UTC_{pred} as reference
- Which is the needed XYTO accuracy for positioning?
  - When should the XYTO be determined or taken from nav message
  - Impact of XYTO errors on the position error
- Conclusions

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



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



CASE 1: conclusion

- $GNSST_i$-$GNSST_{mean}$ provides an accurate access to XYTO for the user
- What matters most is:

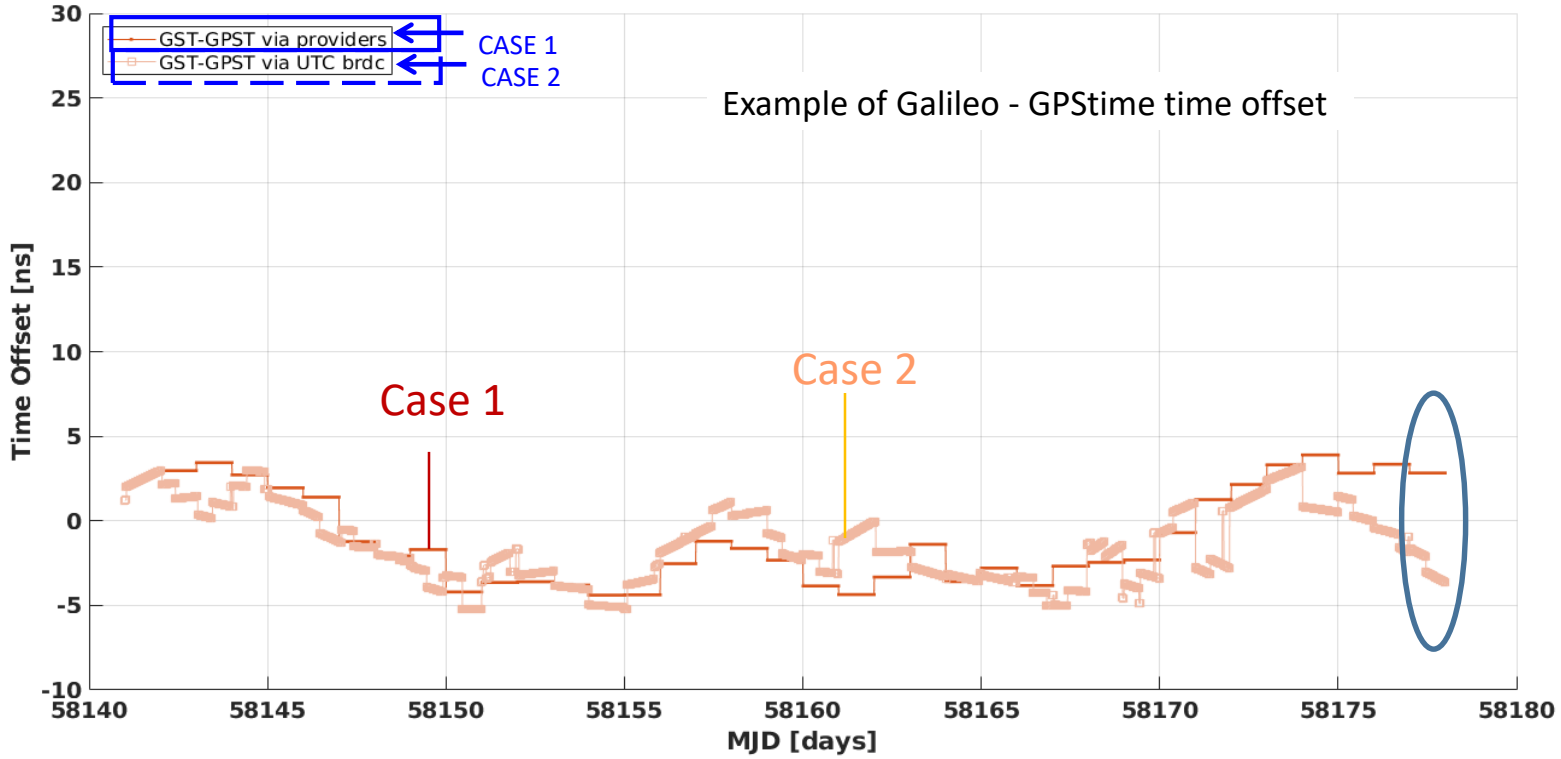
Not the different visibility of satellites

but the calibration of each GNSS provider Rx is fundamental as residual bias of abour 5 ns are often observed

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

$$XYTO = [GNSST_x - UTCbrdc_x] - [GNSST_y - UTCbrdc_y]$$

Difference can be several ns (or more)



Conclusion on CASE1/CASE2

- CASE 1 XYTO, assuming all systems brdc GNSSTi-GNSSTmean
- CASE 2 XYTO, based on Brdc UTC-GNSSTi prediction in the Navigation Messages

	accuracy	System level
$GNSST_{mean}$	5 ns	Need for calibrated receiver and algorithm (same as current GGTO by Galileo)
UTC_{pred} (brdc)	10 (20?) ns	Nothing – except maintaining UTC_{pred} close to UTC

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 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.

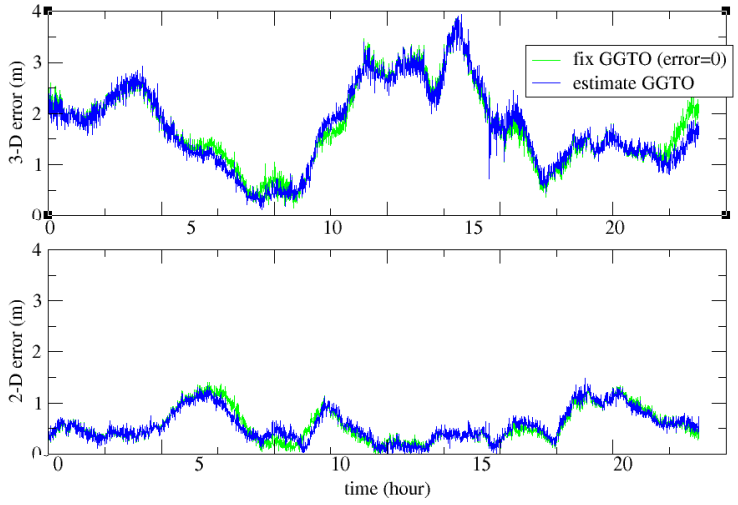
Impact of XYTO accuracy on positioning

- Use GPS+Galileo data and GGTO
- Station in Brussels with good visibility
- 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

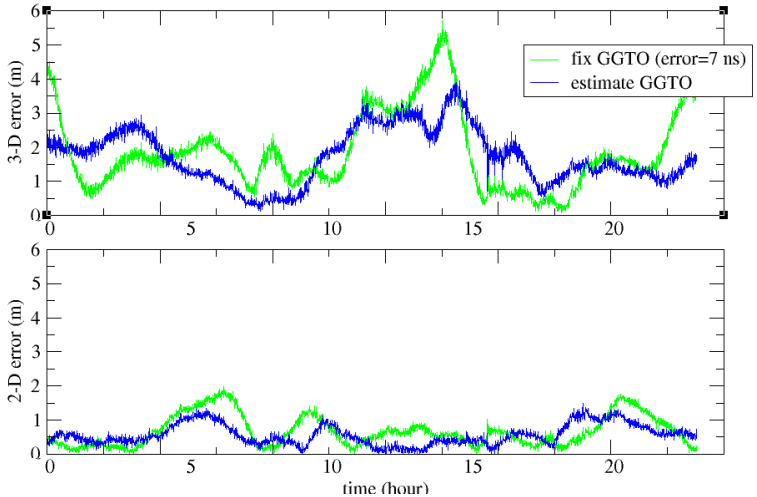
Horizontal Position error over time

No elevation cutoff

Correct GGTO (for the receiver)



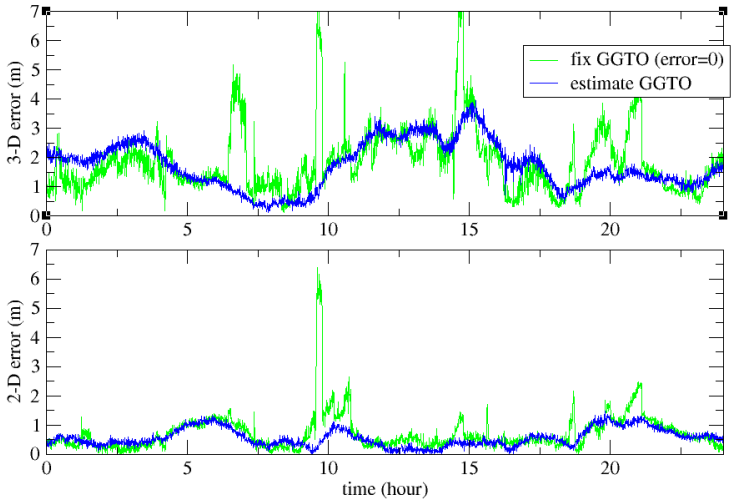
GGTO "error" 7 ns



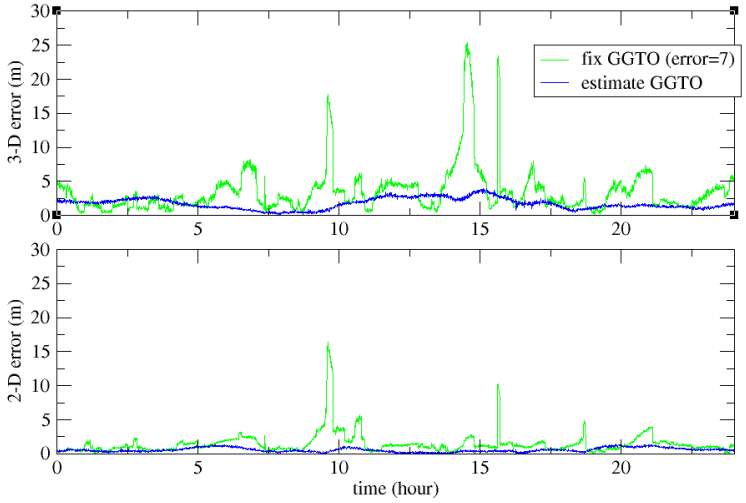
Horizontal Position error over time

Cutoff 30°

Correct GGTO (for the receiver)



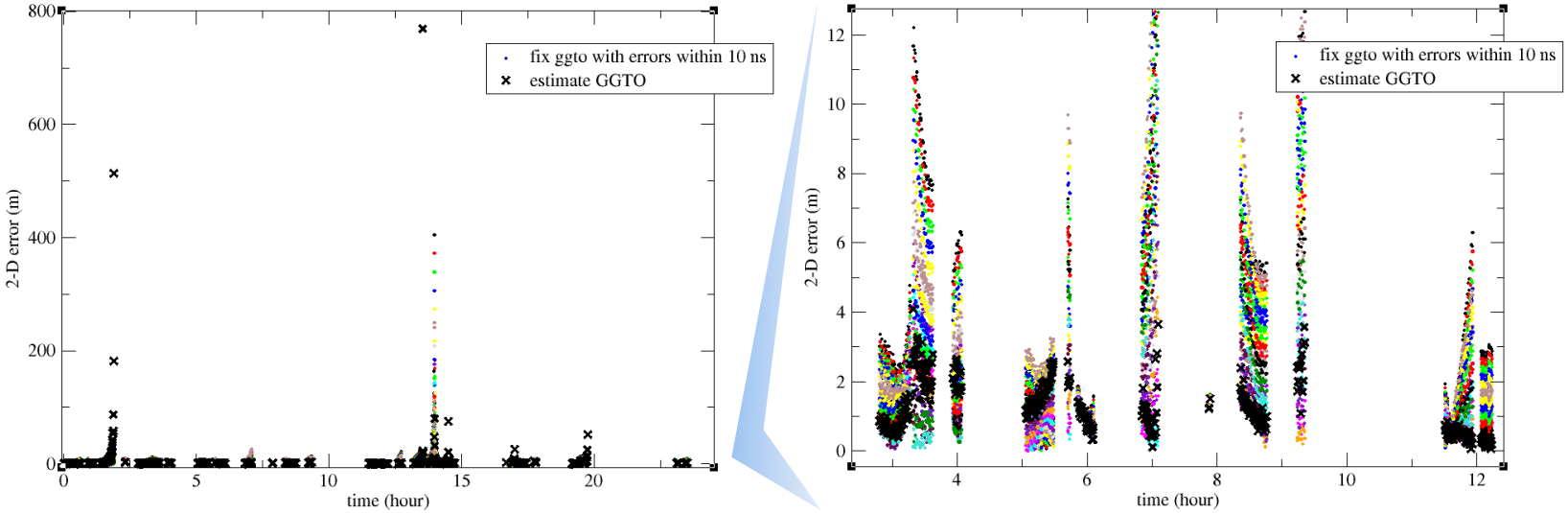
GGTO error 7 ns



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°)



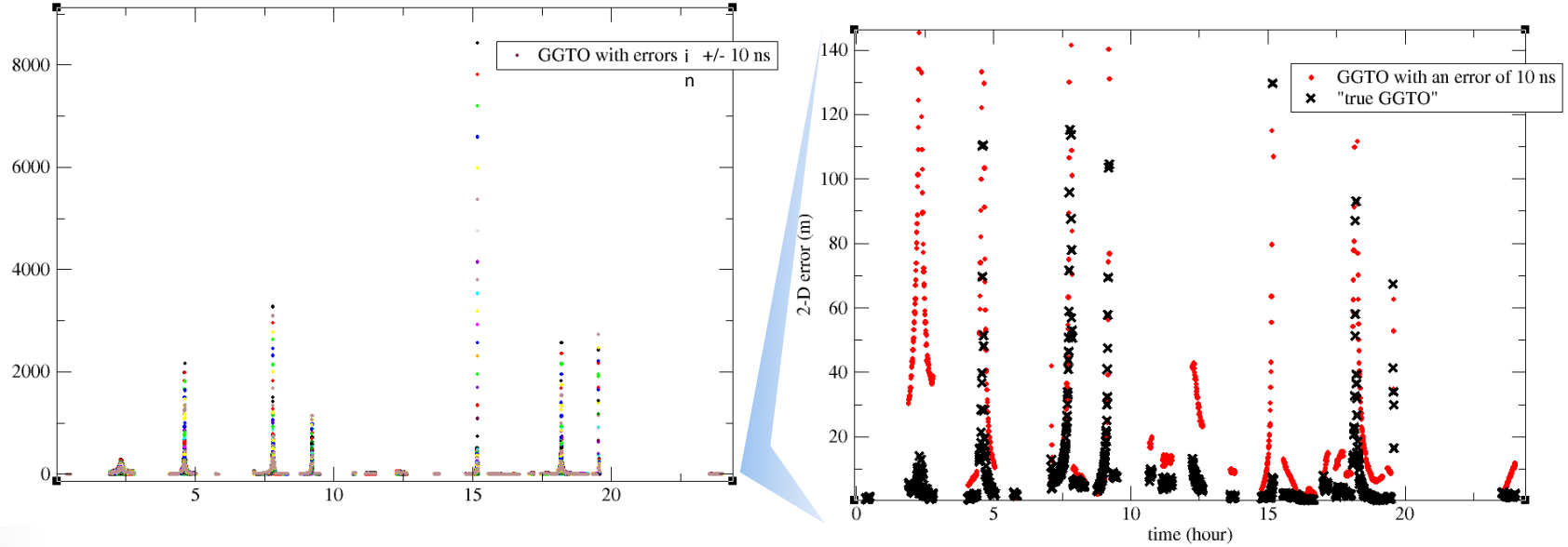
- Estimate GGTO is generally better,
- furthermore, not always the same ‘fixed’ GGTO gives the best solution.
- Conclusion :
  determine GGTO as soon as possible, even with 5 satellites

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”

How getting the "correct GGTO"?

Correct GGTO = GPST-GST-HW(receiver)

- From Nav message → uncertainty of several ns.
- From a previous estimation : uncertainty depends on the time elapsed since the last estimation in view of
  - the stability of the GNSST
  - the stability of the HW delay

Conclusion (1/2)

- A correct XYTO at receiver level is always 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 determination
- When not enough satellites are available to determine a YXTO, a fixed value should be used, either from a previous estimation by the receiver (the best) or from the navigation message
- In that case, horizontal position errors can be large even with the correct GGTO (> 200m),

Conclusion (2/2)

- The accuracy needed on the broadcast XYTO should be based on the expected position accuracy in canyons,
  Example : for 100 m horizontal, we got
  98.0 % of the time (with 4 sat) for the “correct GGTO”
  93.5 % of the time (with 4 sat) for an error of 10 ns (which is expected as the range of error due to HW delays of the receiver)

- 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 within10 ns