# GNSS processing techniques : Review of some topics for the coming years

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- Goal: push down the present performance of GPS (GNSS) T/F transfer
  - ~ $1x10^{-15}$ @ 1 day in frequency
  - ~ several hundred ps in time??

- Some topics in this direction:
  - Precise Point Positioning with integer ambiguity resolution
  - New codes and new combinations (e.g. Galileo)
  - The problem of code (and phase) biases

# Precise Point Positioning with integer ambiguities

- Precise Point Positioning (PPP) using phase and code measurements is a technique of choice for time transfer
- Phase ambiguities are integer but usual PPP is done solving real-valued ambiguities
- Random errors in ambiguity determination may accumulate and generate some Random Walk Phase Noise (RWPN) behavior

  –After XX days, this RWPN may reach the level of code noise
  –At very long term, phase+code may be equivalent to code only

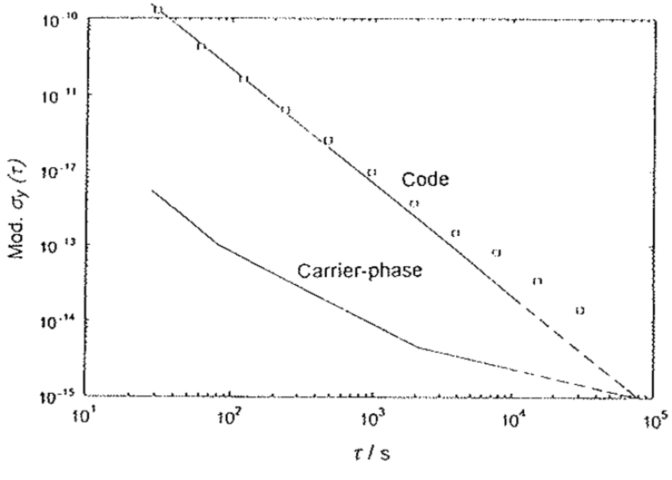


Figure 5: Uncertainty of GPS frequency transfer (see text)

- Using integer ambiguities would eliminate this RWPN behavior
  – If data is continuous, frequency transfer could even be done with phase only.

# Precise Point Positioning with integer ambiguities 1 - Products

- In the standard IGS solutions, SV biases are mixed with SV clocks
  - Impossible to apply
- PPP with integer ambiguities needs special products. A number of analysis centers have started developing such products
  - We have started collaboration with the CNES-CLS IGS Analysis Center "GRG" in Toulouse
  - We will continue cooperation with CNES-IGS and NRCan on this issue

- "GRG" products based on the processing of a global network of ~130 GPS stations and an innovative strategy :
  - identification of hardware (Wide-Lane) Satellite Biases (called WSB)
  - zero-difference phase data processing with Integer ambiguity resolution
    (iono-free phase combination, ambiguity wavelength 10.7 cm)
- GRG GPS satellite phase clock solution properties :
  - continuous between two successive (daily) batches modulo an integer number of (10.7 cm) cycles
  - If 10.7 cm ambiguities can be resolved at batch boundaries, PPP and receiver clock can be obtained indefinitely with integer ambiguities.

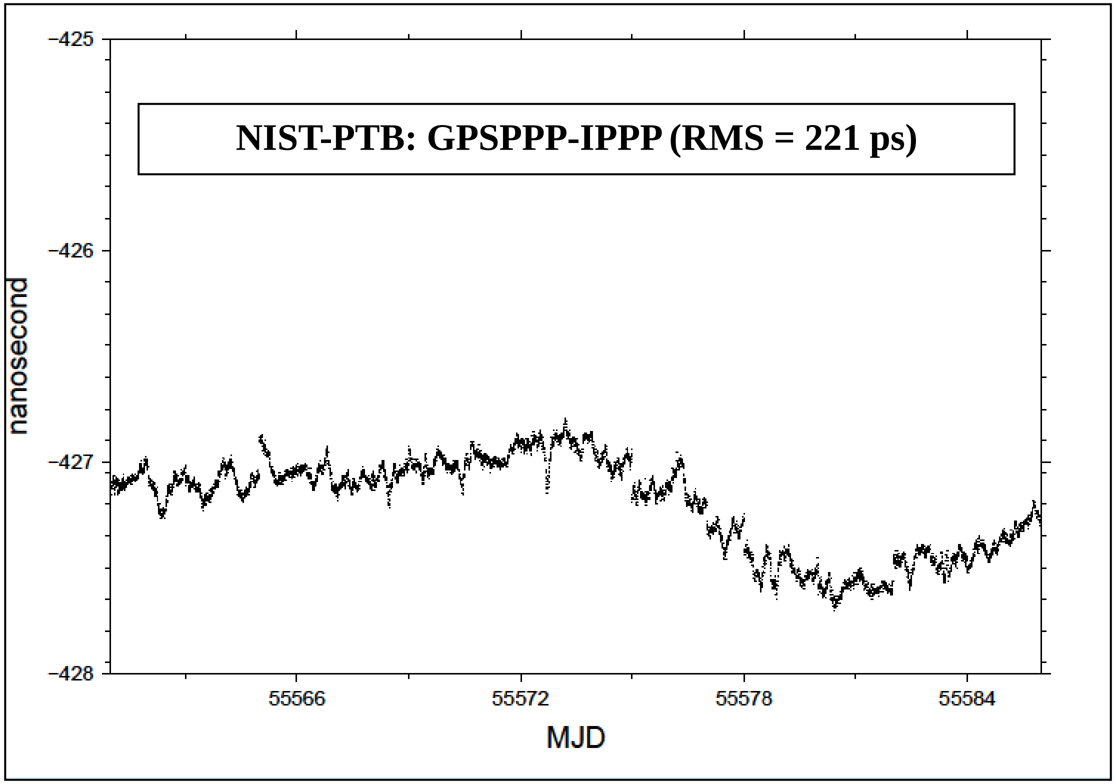
# PPP with integer ambiguities -2: PPP computation

- With the CNES/GRGS GINS software
- Ambiguity fixing 2 step approach :

  1. Wide Lane fixing : GRG WSB are applied at the Wide-Lane combination level.
  An integer solution for N2-N1 is determined and corrected in the iono-free phase combination

  2. N1 (so N2) is estimated using a bootstrapping method on the iono-free phase combination

- Example of comparison of IPPP with GPSPPP: NIST-PTB 1101



# New codes and new combinations (e.g. Galileo)

- Example of Galileo AltBOC on the L5 frequency (all material from Mari Carmen Martinez Belda's PhD thesis)

- **GPS time transfer:** combination of codes in 2 frequencies to remove the ionospheric delay $\Rightarrow$ increase of the noise level
- **Galileo:** $E_5$AltBOC code very precise (very low range noise and multipath error)
  - very promising for improving the medium-term stability of GNSS time transfer
  - BUT should be used without combining it with any other existing code

  $\Rightarrow$ Main limitation: ionospheric delay

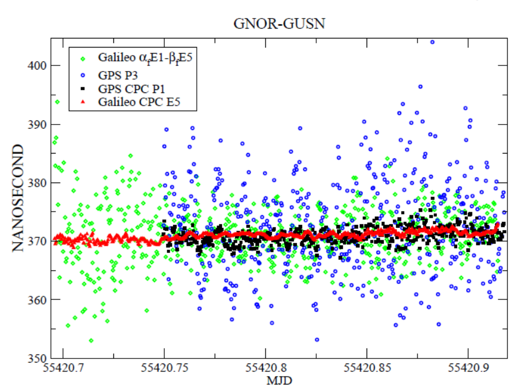
$E5CPC$ APPROACH

1. Geometry-free combinations $\rightarrow$ ionospheric delay
2. Correct $E5CMC$ for the ionospheric delay and determine its ambiguity
3. Correct $E5CPC$ for the ambiguity and solve for the clock

$\Rightarrow$ $E_5$-only and $E5CPC$ approaches have the same average as with the approach with dual-frequency ionosphere-free code
$\Rightarrow$ BUT $E5CPC$ noise level is half the noise level of $E_5$

## GALILEO $E_5$ CODE-PLUS-CARRIER COMBINATION ($E5CPC$)

Comparison between $E5CPC$ & other GPS and Galileo ionosphere-free combinations (clock differences)




1 common track of GIOVE B / GPS PRN19)

**Noise level of $E5CPC$ about 0.5 ns**



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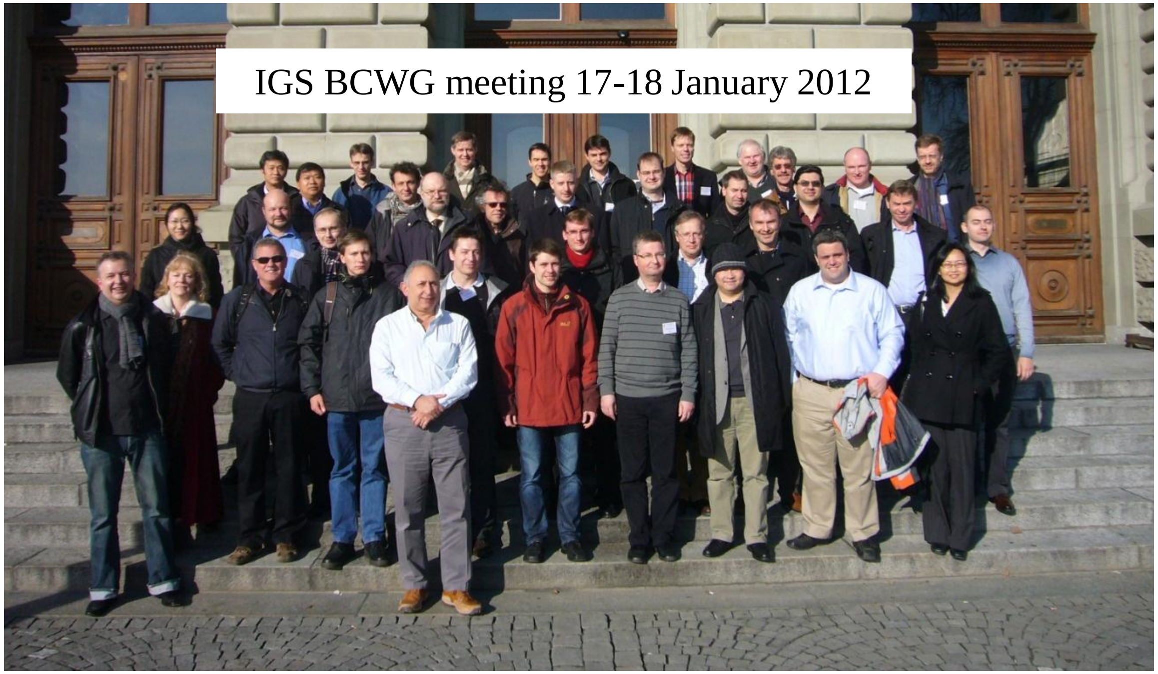
# The problem of code (and phase) biases

- IGS has a Bias and Calibration Working Group (BCWG)
- Maintains operational determination of GPS biases (P1C1, P2C2, P1P2, quarter-cycle biases)
- Starts developing homogeneous treatment for GLONASS interfrequency biases
- Galileo biases expected to be smaller but more numerous

It is likely that GNSS biases will quickly outnumber the participants in the BCWG

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