Positioning with Single and Dual Frequency Smartphones Running Android 7 or Later

*René Warnant, *Laura Van De Vyvere, +Quentin Warnant

*University of Liege-Geodesy and GNSS

+Augmenteo, Plaine Image, Lille (France)

ION GNSS+ 2018, Miami, 26 September 2018.

Raw GNSS data from Smartphones

- In May 2016, Google announced that Raw GNSS Measurements collected by Smartphones running Android 7 and later would be made available to users
- Up to Android 6, only the computed position ("manufacturer receipt") and ancillary satellite information were available.
- Raw Data available on "compatible" Smartphones :
  - Code Pseudorange
  - Accumulated Delta Range (Phase pseudorange) – Not available on all smartphones
  - Doppler
  - CNo

Raw GNSS data from Smartphones : Duty Cycle

- The Duty Cycle is implemented by smartphone manufacturers to save battery power.
- The navigation chip is periodically switched on (200 ms /1 s) and off (800 ms/1s).
- This does not prevent the user to get a code-based solution every second but phase measurements are not continuous.
- Nevertheless, after a "cold" start, the navigation chip remains ON during a few minutes while decoding the message ➔ 4-5 minutes of continuous phase.

Raw GNSS data from Smartphones : Ambiguous code

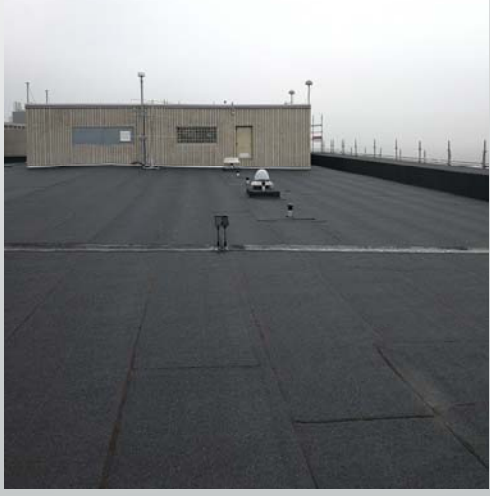
- When the receiver code is locked to the satellite code, the code pseudorange measurement is still "ambiguous" (time modulo)
  - For example, 1 ms modulo for GPS C/A Code.
- The synchronization is done in several steps using the navigation message until the TOW is decoded
  - Different time modulo (GPS): 1 ms, 20 ms, 6s, 1 week.
- ! Raw GNSS Smartphone data contain ambiguous code pseudorange measurements !

GNSS equipment: Smartphones

- Single frequency (SF) smartphones running Android 7 (2017) or Android 8 (2018):
  - Huawei Mate 9 and Samsung Galaxy S8 (Duty Cycle ON)
  - As both smartphones have similar performances, only S8 results are discussed.
- Dual frequency (DF) smartphones running Android 8.1:
  - 2 Xiaomi Mi 8 with Broadcom BCM47755 chip (June 2018)
  - Second frequency available for GPS, QZSS (L5) and Galileo (E5a).
  - ! Duty Cycle OFF !
- Multi-constellation:
  - GPS, GLONASS, Galileo, Beidou, QZSS (available but not processed so far)
- Raw Data acquisition using GNSS Logger (Google).

The data

- All data used in this study have been collected on the roof of our building (open sky) close to our geodetic receivers.
- At the moment we focus on the "best achievable" results with smartphones.
- Two types of experiments:
  - Short sessions (10-min) with one smartphone "alone".
  - Short baseline sessions (up to 60 min) with 2 or 3 smartphones close to each other.



Xiaomi: L5/E5a versus L1/E1

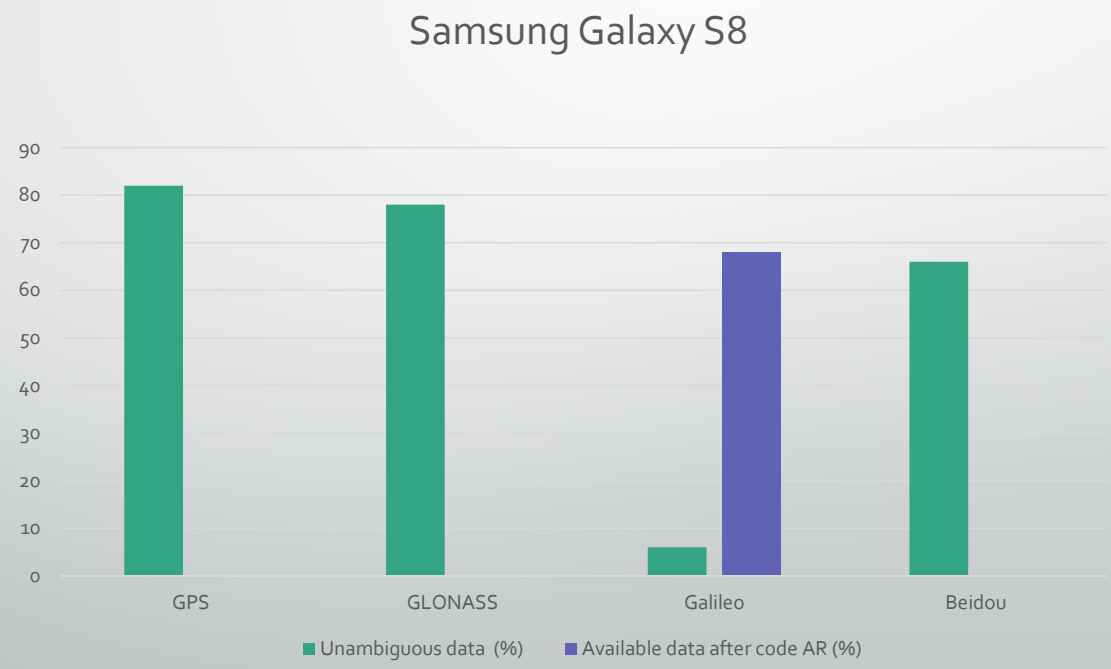
- L5 (E5a) CNo is systematically lower than L1 (E1) CNo
- Nevertheless L5 (E5a) precision is significantly better than L1 (E1).
- The number of L5 (E5a) observations is smaller than L1 (E1)
  - About 50 % for GPS
  - Often the same or a bit smaller for Galileo.
- The available number of L5 (E5a) measurements is usually sufficient to compute a GPS+Galileo L5+E5a solution.

Galileo tracking for SF Smartphone

- All SF smartphones used in our study are Galileo compatible, nevertheless, Galileo tracking is not always "straightforward".
- Usually, the tested SF smartphones are NOT able to track all Galileo satellites in view (not considering unhealthy satellites).
- The situation has been slowly improving with software upgrades.
- Nevertheless, even if Galileo satellites are tracked, most code pseudoranges remain ambiguous on SF smartphones.

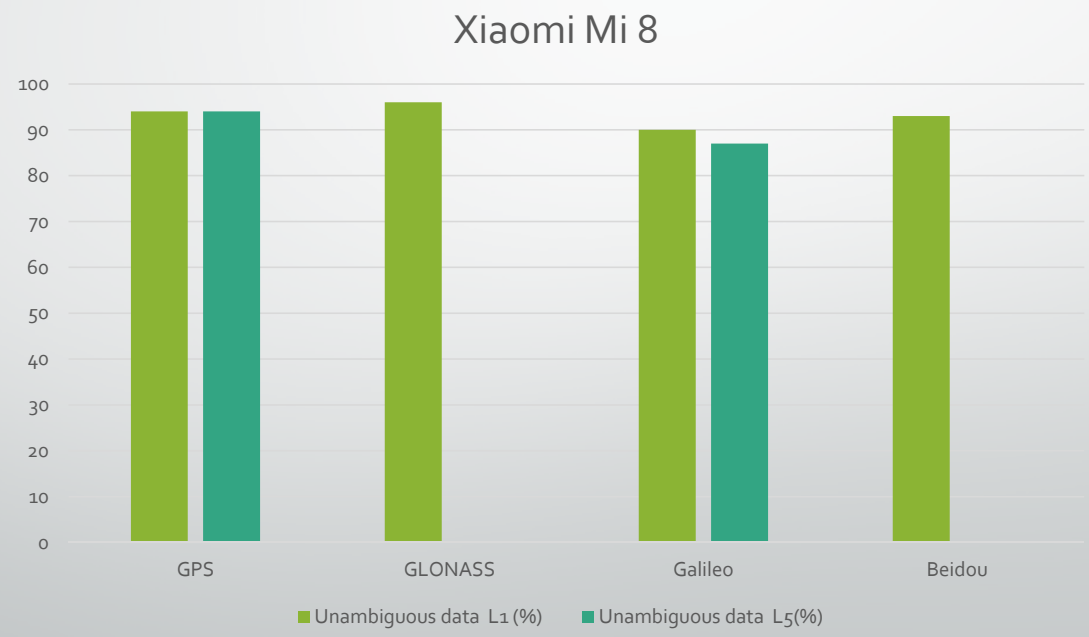
Proportion of ambiguous code pseudoranges SF

- Percentage of unambiguous code pseudoranges wrt all available data (Samsung Galaxy S8) based on 15 ten-minute sessions.
- Ambiguity (time modulo) resolution is necessary for Galileo



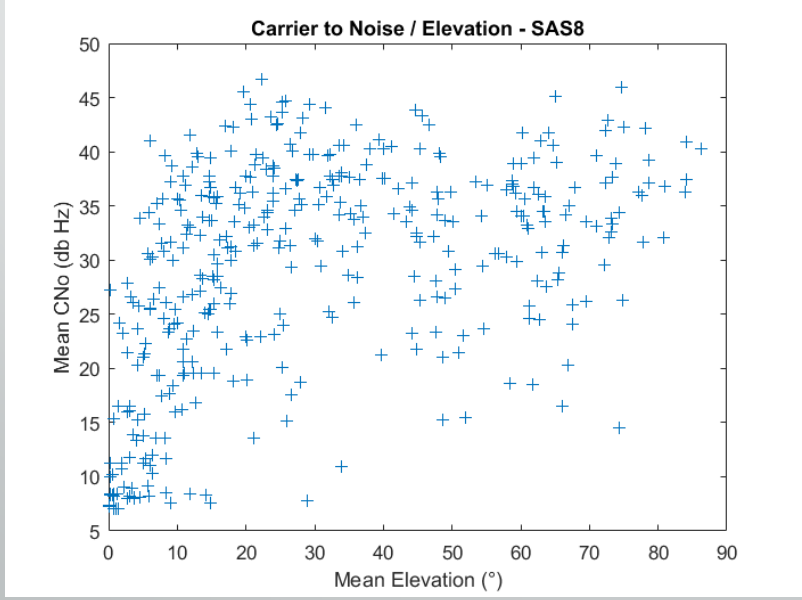
Proportion of ambiguous code pseudoranges DF

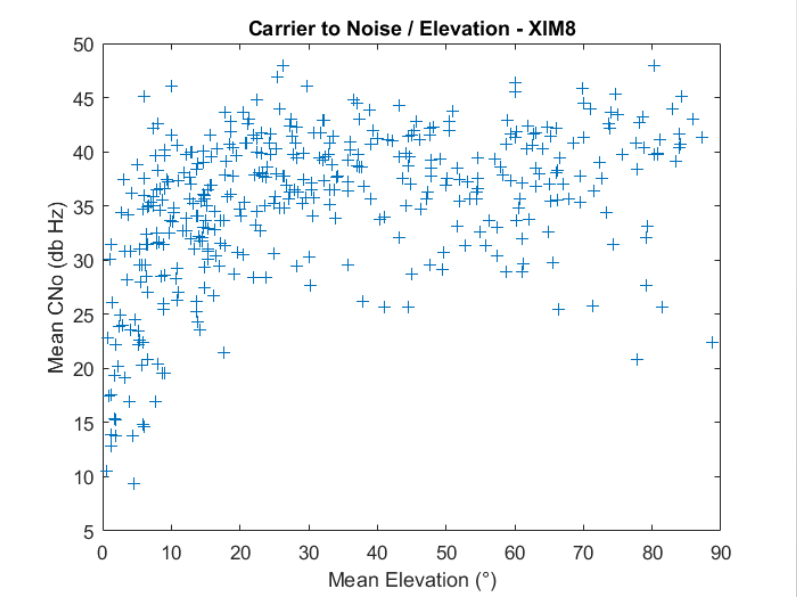
- Proportion of ambiguous code pseudoranges wrt all available data (Xiaomi Mi 8) during 15 ten-minute sessions.
- ! Ambiguity resolution for Galileo is NO longer necessary !



CNo and elevation

- When using Geodetic receivers, CNo increases with satellite elevation.
- In data processing techniques, this characteristic is often exploited in the variance-covariance matrix of the observations.
- Raw GNSS Smartphone data do not behave in the same way meaning that data processing strategies must be modified accordingly.

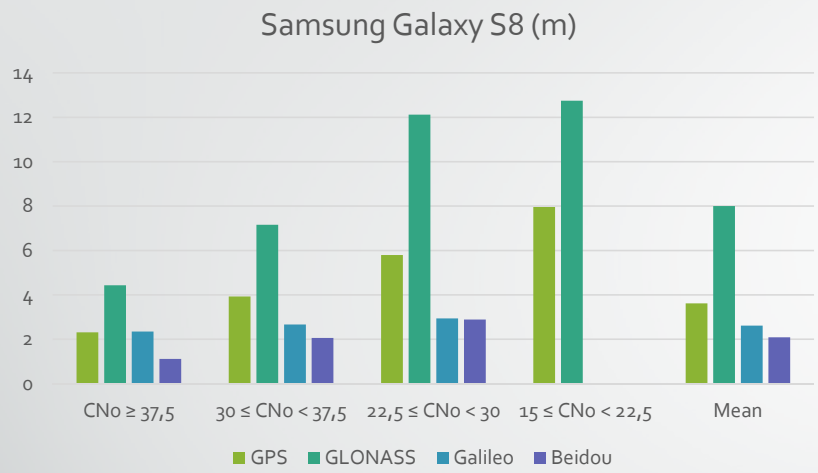


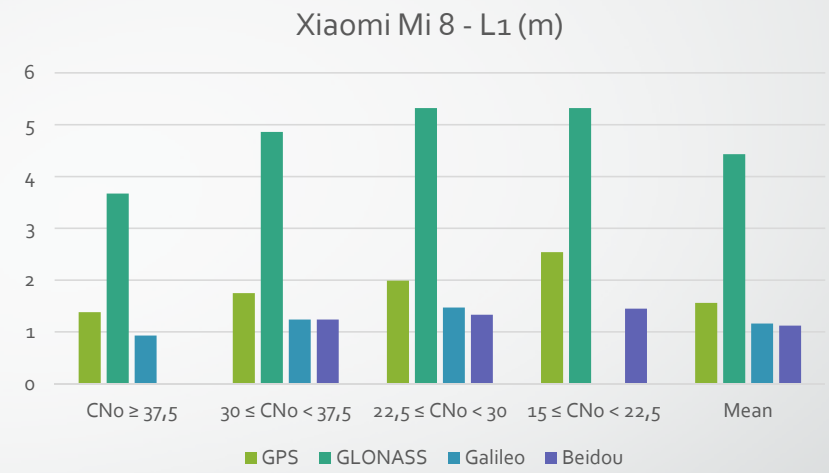


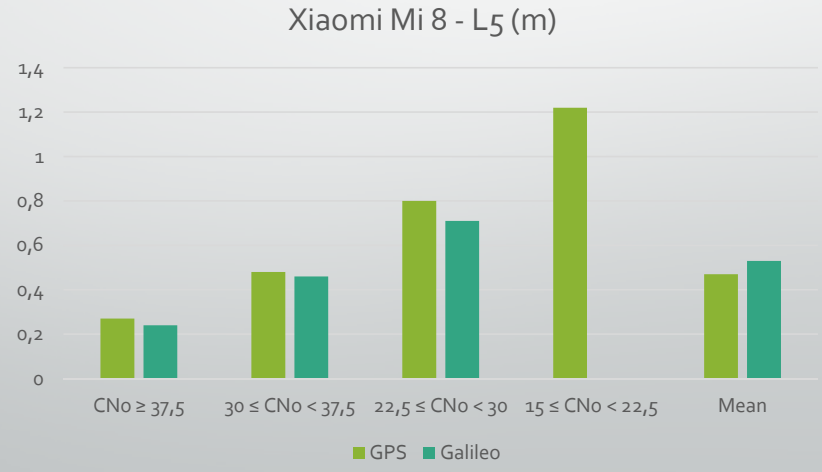
Code precision

- Code precision is assessed using 2 combinations.
- Code Range Rate Minus Phase Range Rate
  - Contains noise
  - Contains between epoch variation of ionosphere and multipath and hardware biases (usually small)
  - Our results are based on 15 ten-minute sessions.
- Code Double Differences on a short baseline
  - Contain noise AND multipath.
  - Our results are based on one-hour short baseline sessions.

Code pseudorange precision depending on CNo

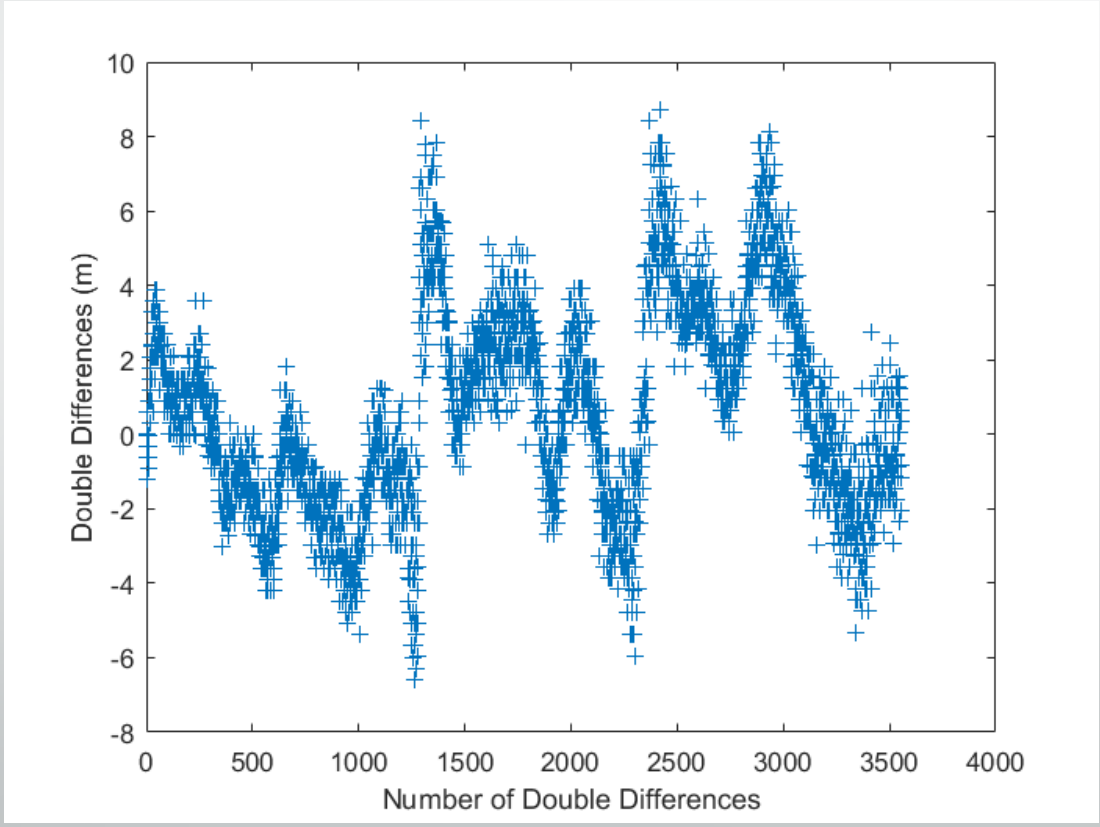






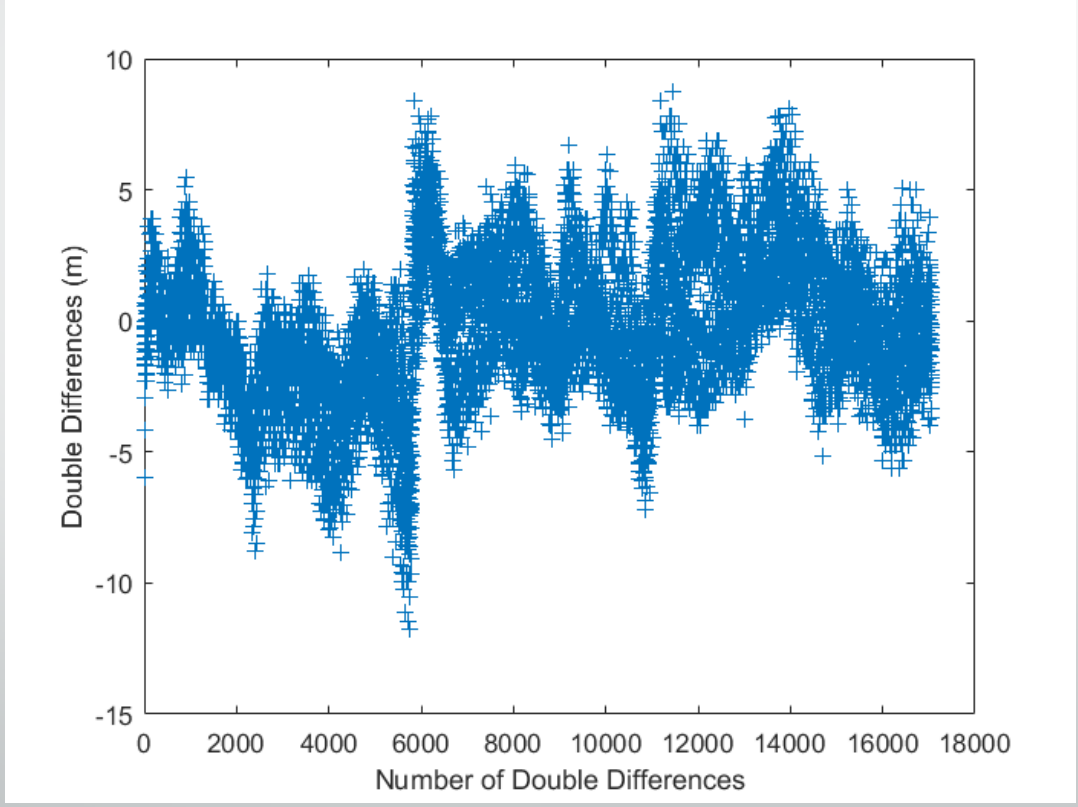
Multipath influence on DD (Xiaomi)

- GPS L5 DD (1 satellite pair) on short baseline.
- Multipath signature can be very easily seen due to the very low noise.



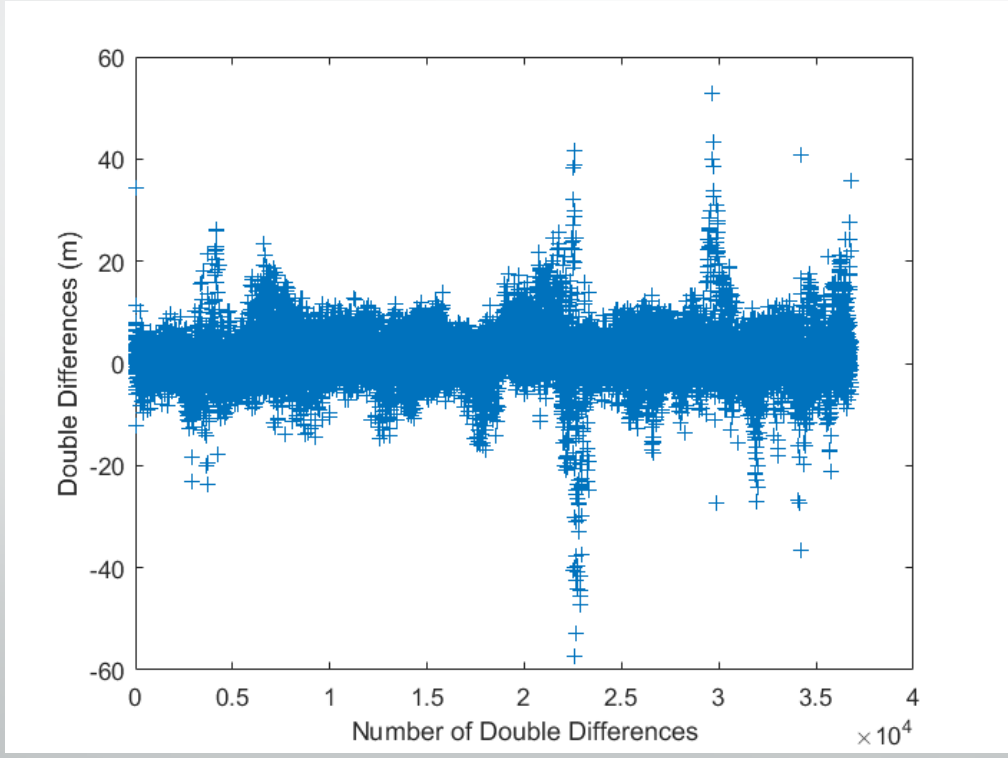
GPS L5 Code precision from DD (Xiaomi)

- L5 Code precision (noise+multipath) : 1,31 m (0,47 m with range Rate)



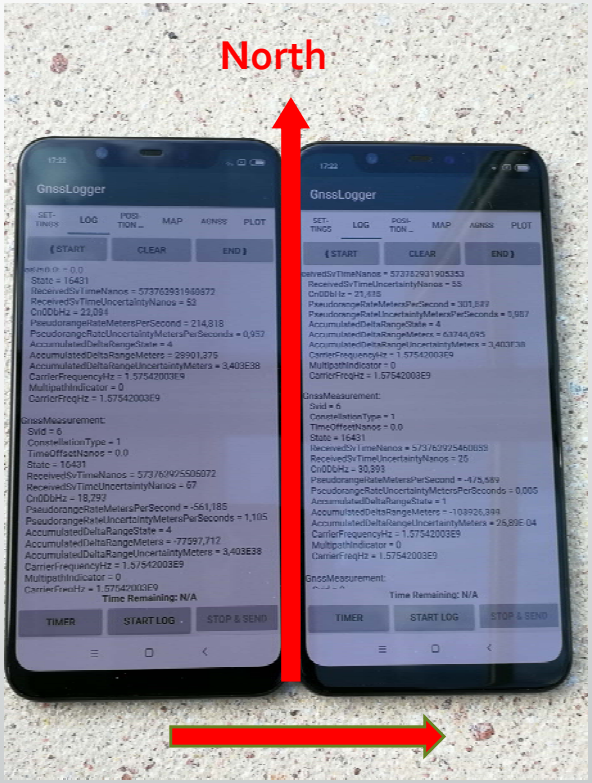
GPS L1 Code precision from DD (Xiaomi)

- L1 Code precision (noise+multipath): 2,10 m (1,56 m with range Rate)
- If not filtered out, strong multipath significantly degrades code-based positioning (in particular when using ionosphere free combination)



Short Baseline experiment

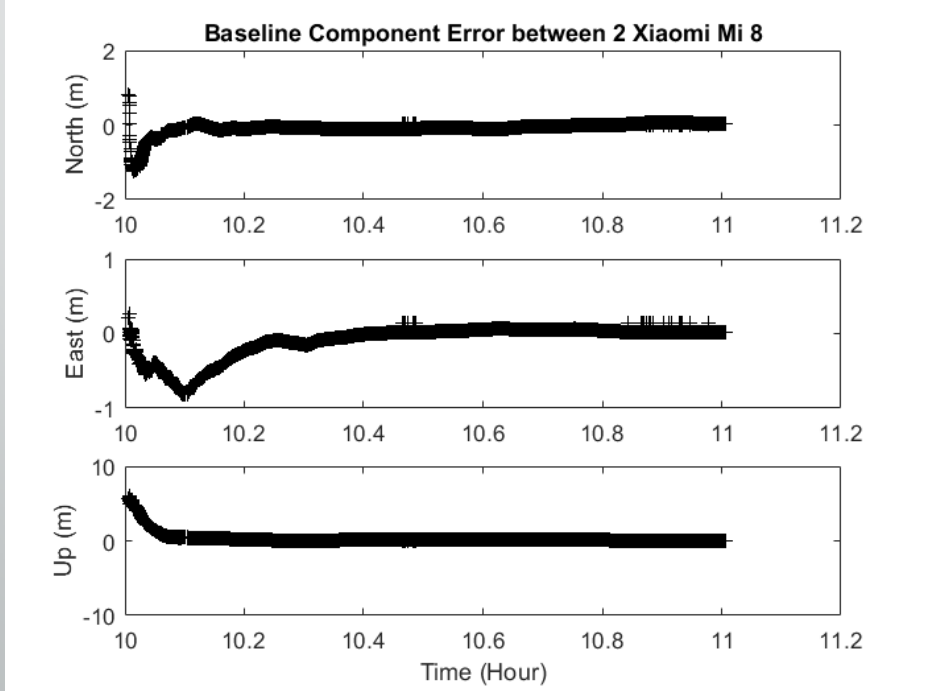
- Short Baseline between 2 Xiaomi Mi 8.
  - dNorth=0,000 m
  - dEast=-0,075 m
  - dUp=0,000m
- 2 Sessions of 1 hour on DOY 246 (03 Sept. 2018).
- Carrier phase-based static differential positioning using GPS and Galileo (L1/E1+L5/E5a)

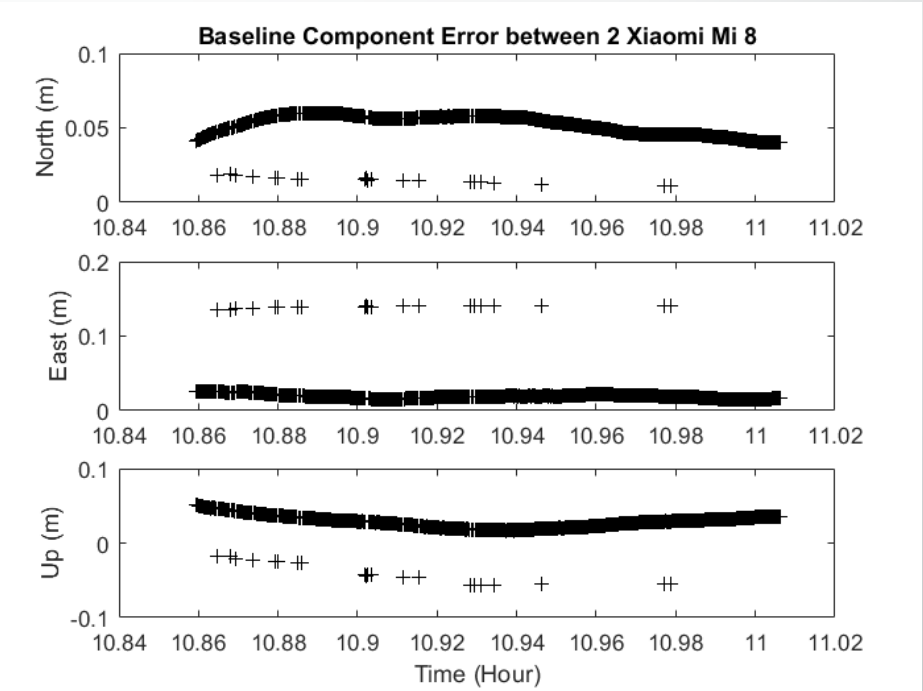


dEast = 0,075 m

Positioning results – Session 1

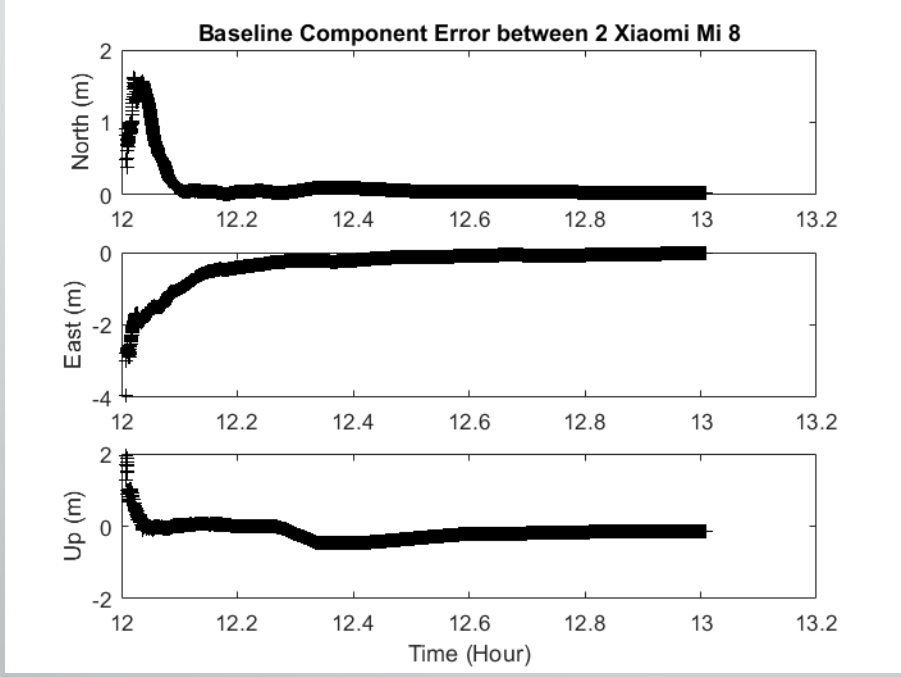
- Session 1: DOY246, 10h00-11h00.
- cm-level accuracy in all components except for a few outliers (dm).

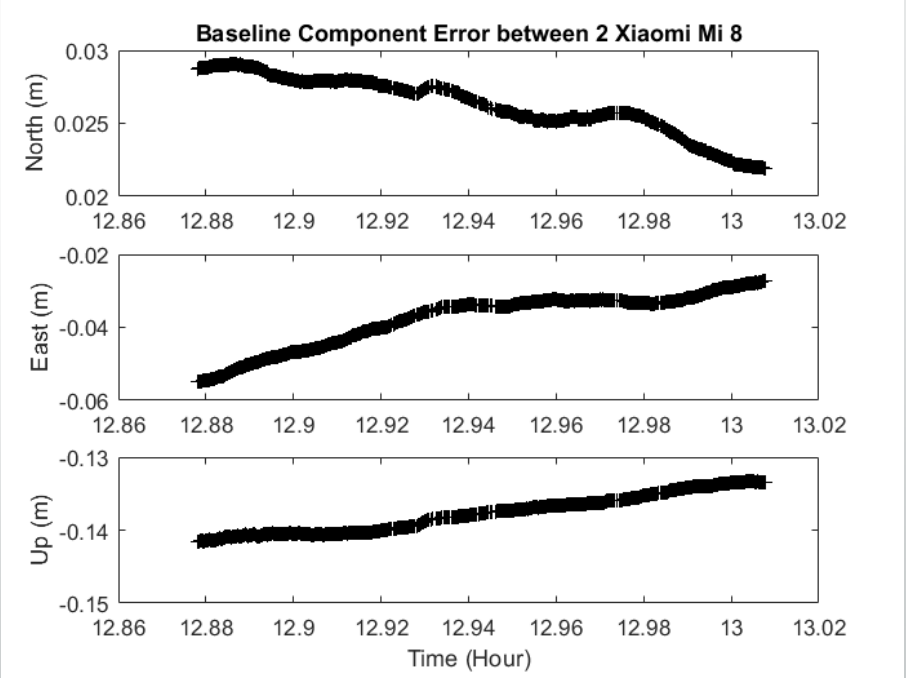




RTK results – Session 2

- Session 2: DOY246, 12h00-13h00.
- cm-level accuracy in horizontal component and dm-level in vertical component.





Conclusions

- Galileo tracking is very much improved on Xiaomi Mi 8: 90 % of the codes are Not ambiguous.
- For both SF and DF smartphones, Code Pseudorange precision is better for Beidou and Galileo than for GPS and GLONASS.
- Xiaomi Mi 8 L1 code precision is about 2 times better than Samsung Galaxy S8 and Huawei Mate 9.
- Xiaomi Mi 8 L5/E5a codes reach a precision of about 20 cm for CN0>37.5 dB Hz but it is still very susceptible to multipath.
- Carrier phase-based static differential positioning using GPS and Galileo (L1/E1+L5/E5a) on a very short baseline provides cm-level precision in horizontal component and decimetre-level in vertical component.