

28 May 2020

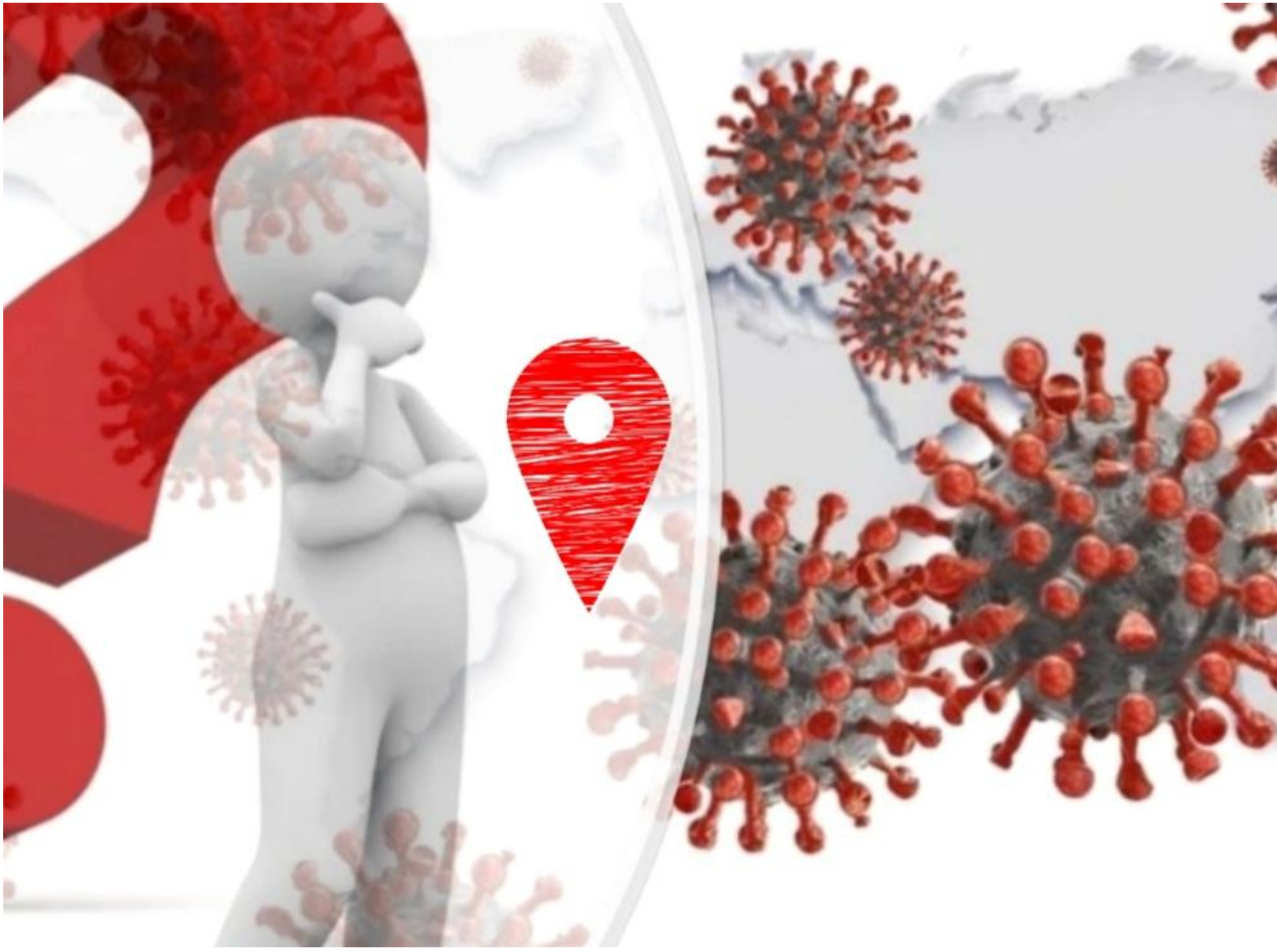
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4th GNSS Raw
Measurements Task
Force Workshop

Precise positioning on smartphones: which implementation strategy to adopt?

 Université
Gustave Eiffel

 TEAM
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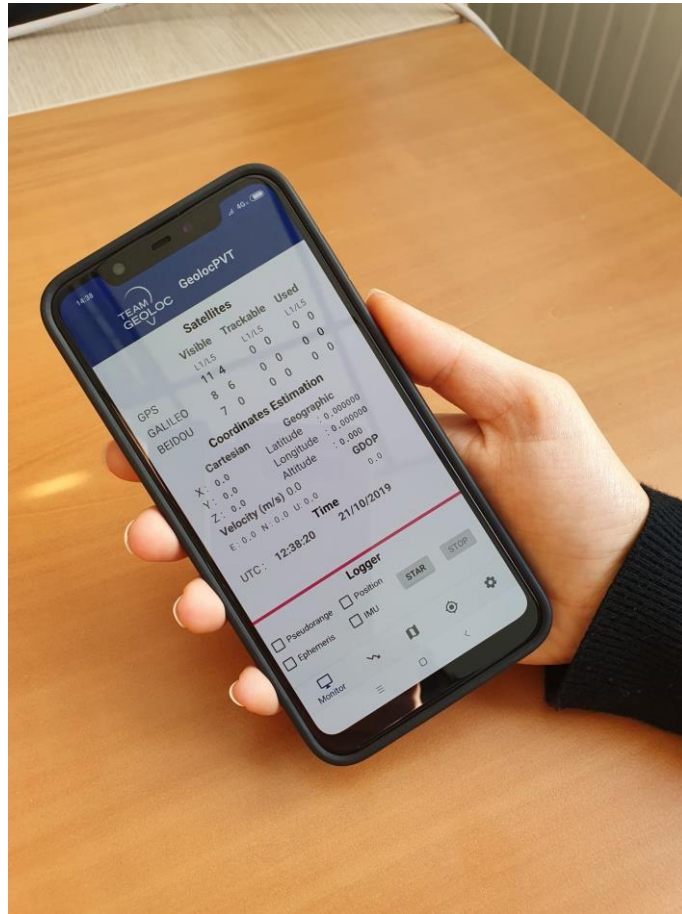
Context

- Since 2016, Google API enables the access to raw GNSS data
→ Enabling the coding of custom positioning algorithms
- Number of published articles on GNSS precision measurement on smartphones continues to increase
- Not so many new smartphones released with a dual frequency (L1/L5) and a full compatible GNSS receiver chipset for raw data
→ 1st one: Xiaomi Mi 8, in 2018
→ 2nd and last one: Huawei Mate 20 X, in 2018 [1]

Model	Android version	AGC	Nav messages	ADR (carrier phase)	L5	Global systems
Huawei Mate 20 X	9.0	no	yes	yes	yes	GPS GLO GAL QZS
Xiaomi Mi 8	8.1	no	yes	yes	yes	GPS GLO GAL BDS QZS

[1] *Android Developers online Resources, 'Raw GNSS Measurements', <https://developer.android.com/guide/topics/sensors/gnss>*

Main objective



Investigate precise positioning, in real-time, on Android device

→ Which methodological choices in our app: GeolocPVT?

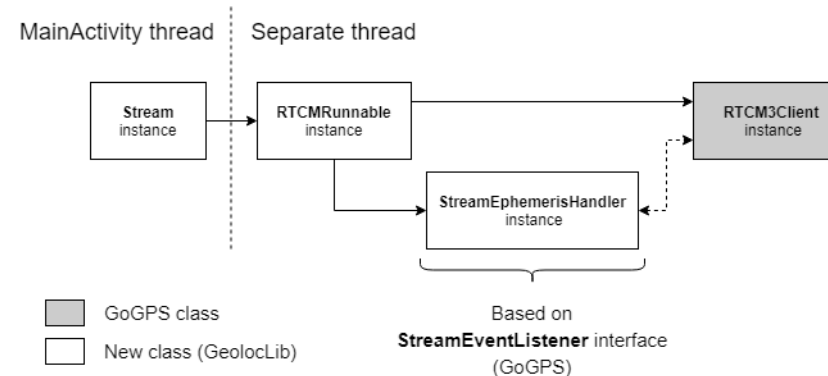
Looking for an autonomous PVT computation?



Expectations	Reality
<p>Precise positioning independent of external connection like the Internet</p>	<p>Navigation messages not available for GALILEO and BEIDOU constellations</p> <p>Solution: Real-Time Service (IGS-RTS) Need Internet connection</p>

Adoption of RTCM streams in GeolocPVT

- Precise corrections and multi-constellations
- Accuracy in ultra-fast products
- 5 sec. sampling rate of satellite clock products
- Access and decoding facilitated by *GoGPS* library



Measurement models for positioning

GNSS positioning based on trilateration

Multi-constellation multi-frequency based positioning

- Corrected receiver-satellite pseudo-ranges
- 4 satellites minimum
- Each constellation adds an inter-system bias

Model used for classical Standalone Positioning

$$P_f^j = \rho^j + c \cdot (\delta t_r - \delta t^j) + \tau_{iono}^j + \tau_{tropo}^j + \epsilon$$

$$\Phi_f^j = \rho^j + c \cdot (\delta t_r - \delta t^j) - \tau_{iono}^j + \tau_{tropo}^j + \lambda_f \cdot N_f^j + \epsilon$$

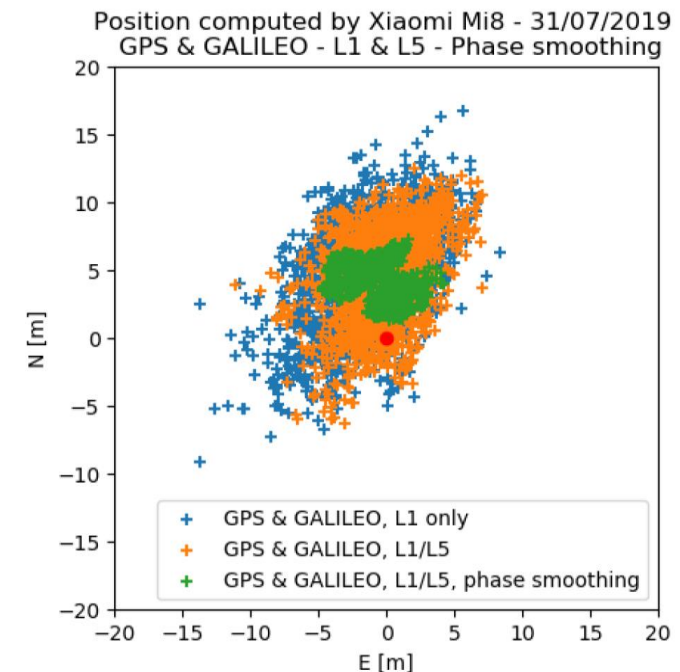
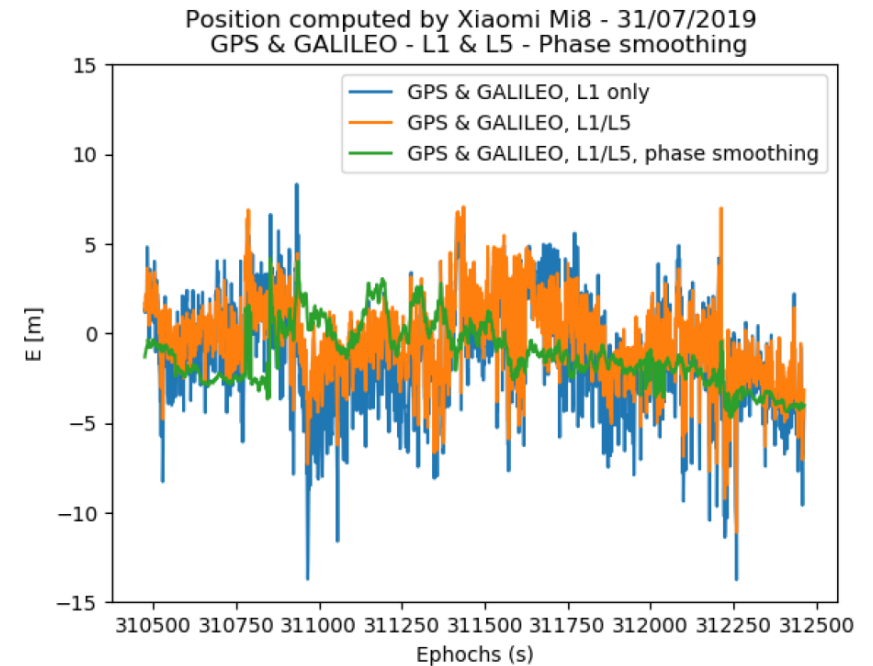
Phase based smoothing of pseudo-ranges

$$\hat{P}_k^j = \frac{1}{n} \cdot P_k^j + \frac{n-1}{n} \left(\hat{P}_{k-1}^j + (\Phi_k^j - \Phi_{k-1}^j) \right) \quad \text{if } k < N, n = k$$

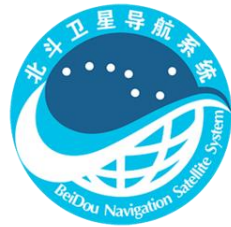
else, $n = N$

Results (RMS 2D 1sigma) :

- GPS & GAL L1 6.7m
- GPS & GAL L1-L5 6.2m
- GPS & GAL L1-L5 smoothed 5.1m



Multi-constellations, dual frequency



Constellations implemented in GeolocPVT

- GPS
- GALILEO
- BEIDOU
- GLONASS in progress



-more satellites : better availability / accuracy

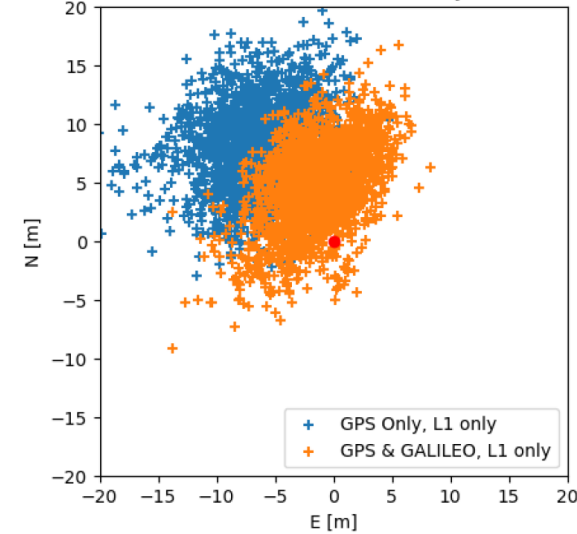
RMS 2D : GPS L1 (11.5m) > GPS & GAL L1 (6.7m)

-more frequencies : better accuracy

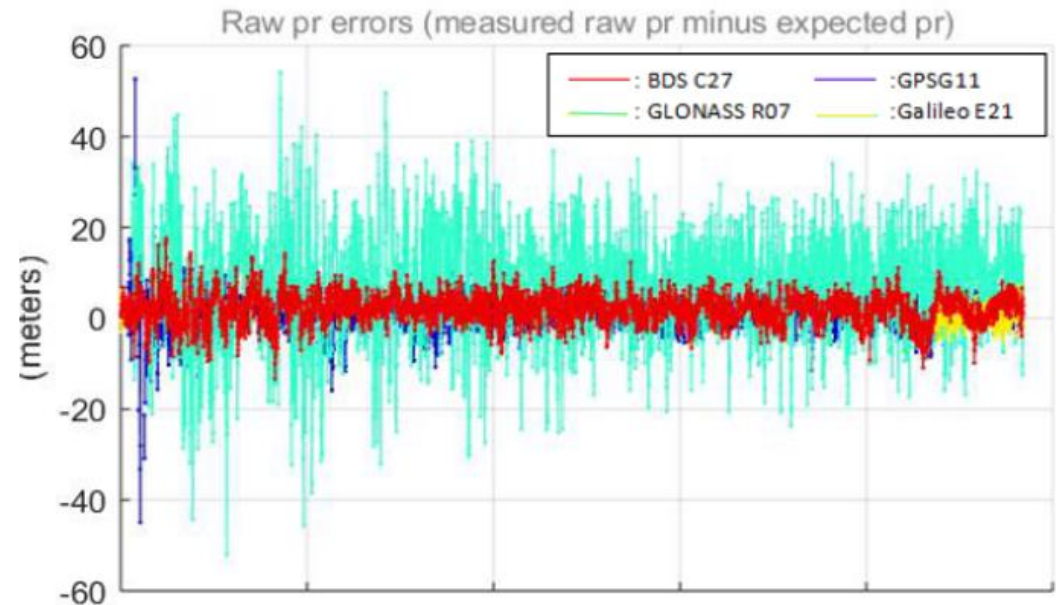
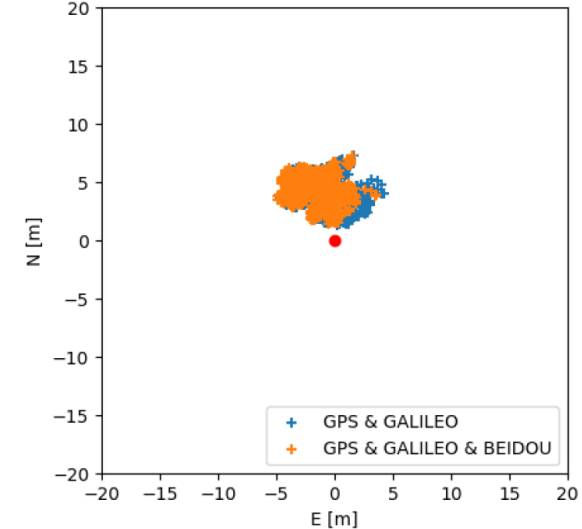
-weighting on pseudorange noise possible

Error GLONASS > GPS > Galileo = Beidou

Position computed by Xiaomi Mi8 - 31/07/2019
GPS & GALILEO - L1 only



Position computed by Xiaomi Mi8 - 31/07/2019
GPS & GALILEO & BEIDOU - L1 & L5 - Phase smooth

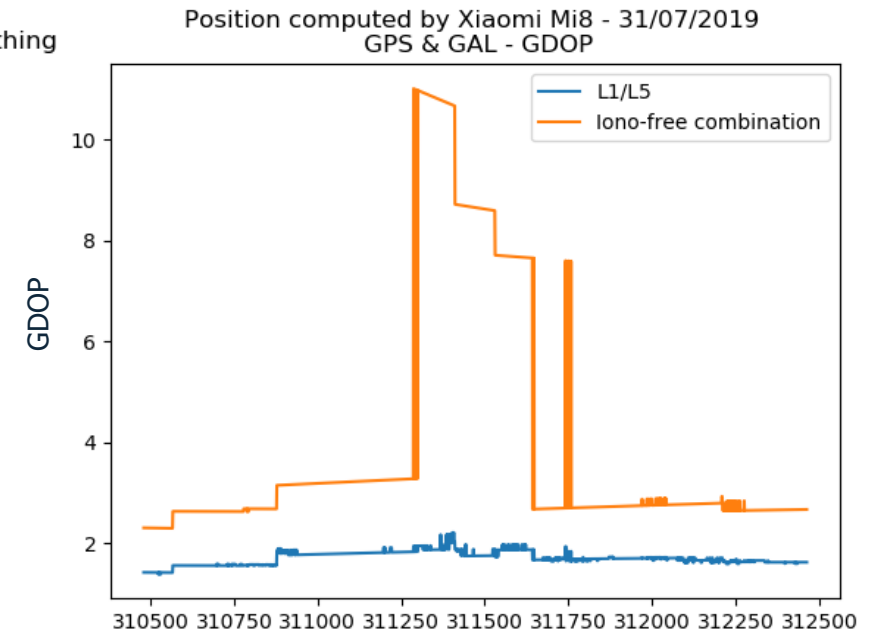
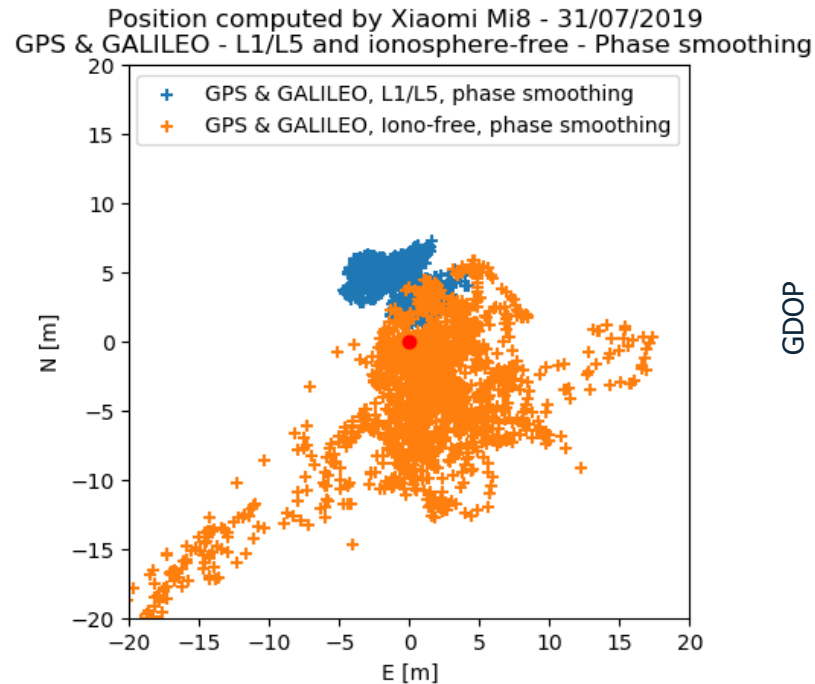


Ionospheric correction

Xiaomi Mi 8 tracks L1 & L5 --> ionosphere-free combination

Results = loss of accuracy

- Only block II-F satellites broadcasting both L1/L5 GPS signals
- Noise of the iono-free combination increases [2]
- C/N0 on L5 smaller than expected



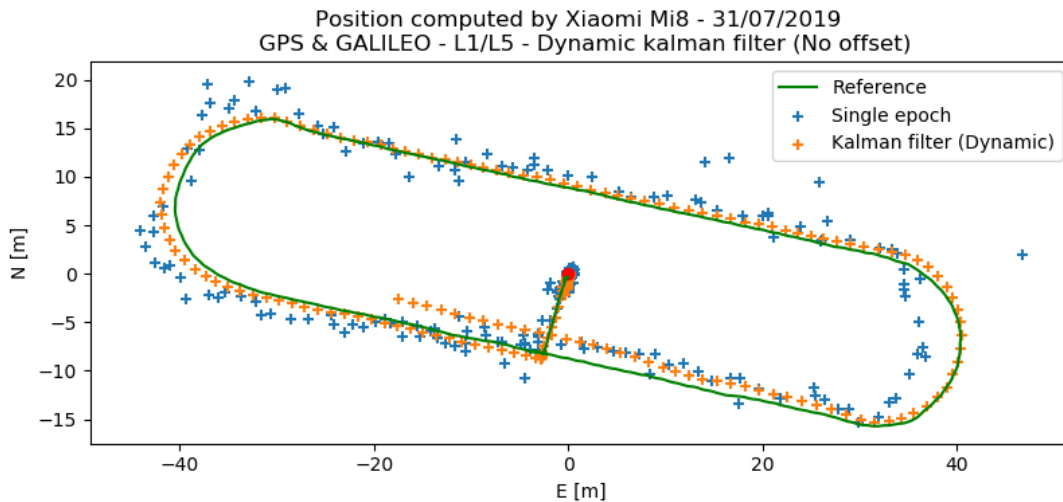
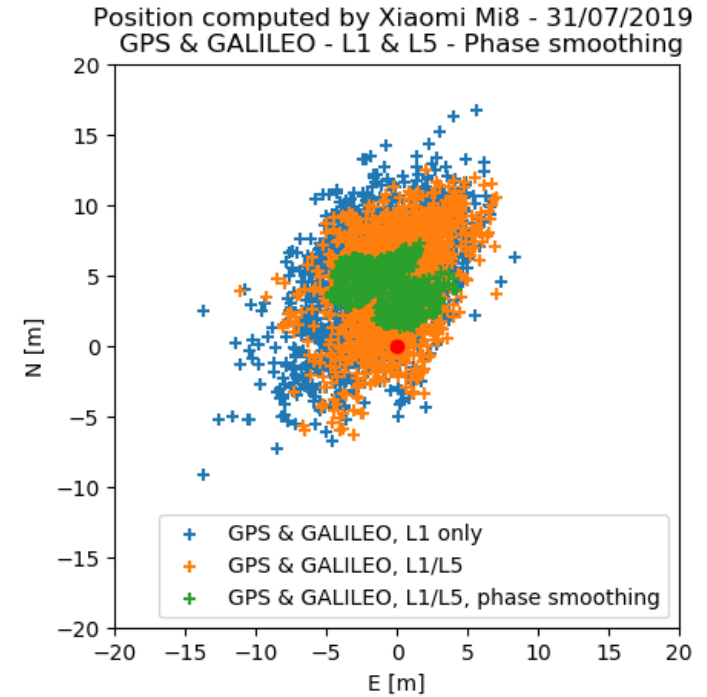
[2] Guo, L., Wang, F., Sang, J., Lin, X., Gong, X., & Zhang, W. (2020). Characteristics analysis of raw multi-GNSS measurement from Xiaomi Mi 8 and positioning performance improvement with L5/E5 frequency in an urban environment. *Remote Sensing*, 12(4). <https://doi.org/10.3390/rs12040488>.

Time-Differenced Carrier-Phase (TDCP) algorithm

Static mode

SPP with pseudo-ranges smoothing

Extended Kalman Filter with pseudo-ranges smoothing



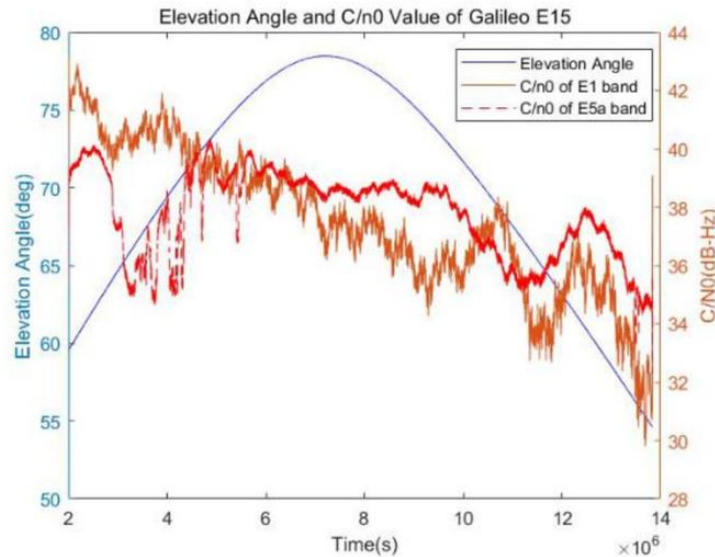
Dynamic mode

Extended Kalman Filter with velocity estimation using time difference between phase measurements at epoch $t_k - 1$ and k

$$\Delta\Phi^j = \dot{\rho}^j + c \cdot \Delta\delta t_r - c \cdot \Delta\delta t^j + \Delta\delta u^j - \Delta\tau_{iono}^j + \Delta\tau_{tropo}^j + \epsilon_{\Delta\Phi^j}$$

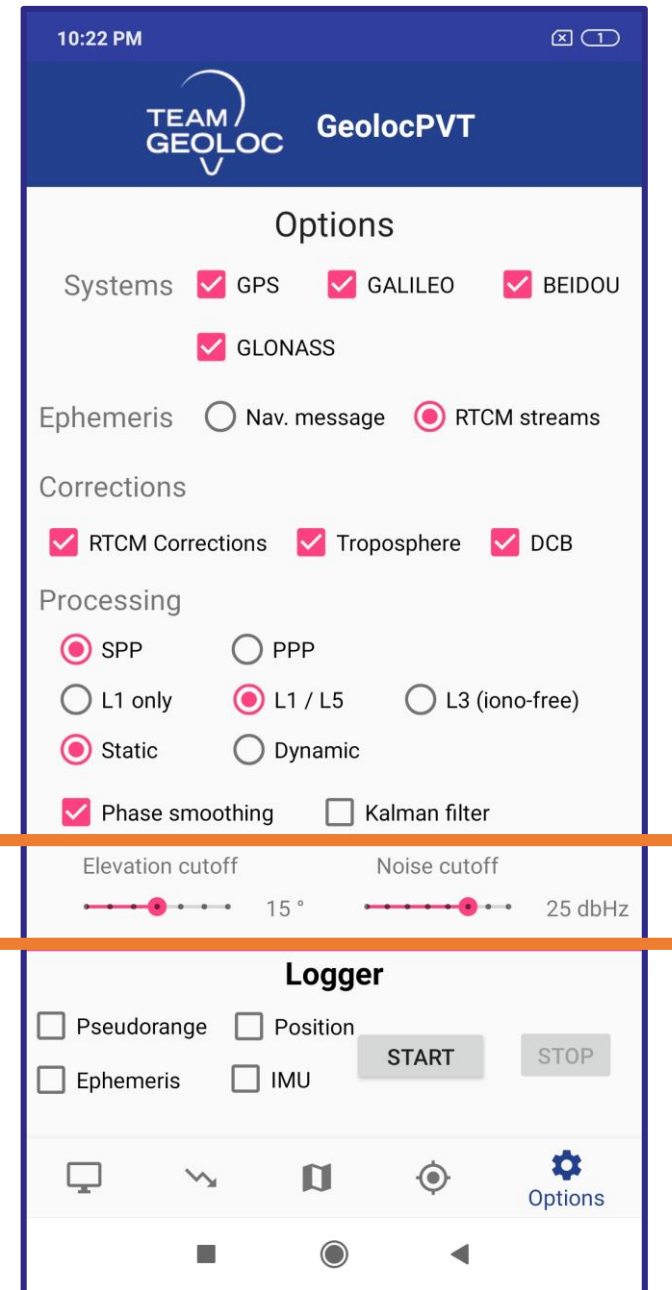
Weighting the GNSS raw data

- **GNSS signal quality on smartphones is independent from the elevation**
 - Elevation cut off not so appropriate
 - C/N0 weighting more adequate
- **In GeolocPVT: cut-off thresholds for both**



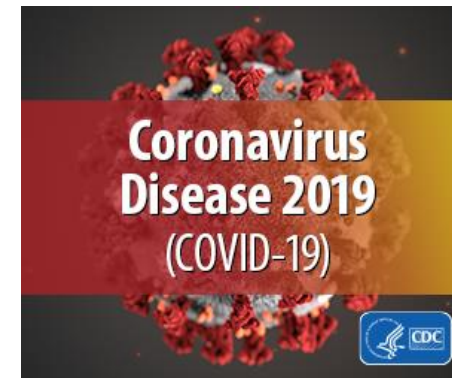
High C/N0 not sufficient: flag STATE_CODE_LOCK has also to be checked

➤ Measurement eliminated if no code lock



Conclusion

- **Many strategies are possible to reach high accuracy positioning**
 - Model of the smartphone?
 - User requirements / uses cases?
- **These are tightly linked to the final application – a question of trade-off**



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<https://gitlab.com/TeamGEOLOC/geolocpvt>

