GSA Raw Measurements Workshop 2020

Updated Google Tools: Logging and Analyzing GNSS Measurements

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27 May 2020, v1.1

android

Outline

- Ecosystem snapshot
- Logging Tools
  - RINEX
  - Sensor logging
  - Updated UI
- Analysis Tools
  - L1,L5 analysis
  - Kalman Filter positions
  - ADR (carrier phase) positions
  - Select satellites for position
  - RINEX
- Android 11
  - Changes and updates to GNSS Measurements API

Raw GNSS Measurements in the Android Ecosystem

2020 Snapshot

Google GNSS Analysis Tools

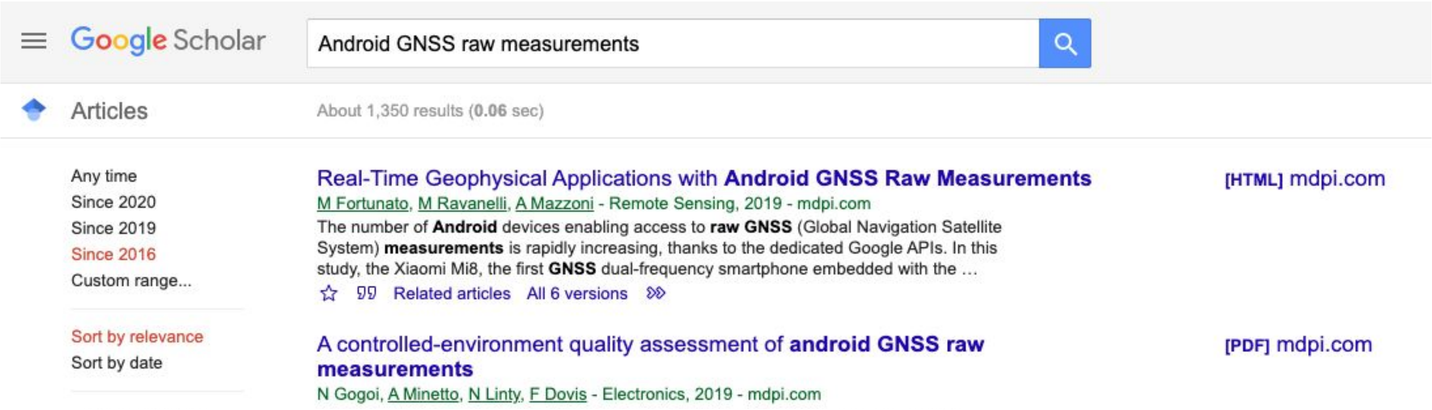
17,000 downloads
(last year: 10,000)

Apps

RTK, PPP, Interference Detection, Health Monitoring, Analysis, ...

Research

1,350 papers
(last year: 900)


Google Scholar

Android GNSS raw measurements

Articles

About 1,350 results (**0.06** sec)

Any time
Since 2020
Since 2019
Since 2016
Custom range...

Sort by relevance
Sort by date

Real-Time Geophysical Applications with **Android GNSS Raw Measurements** [HTML] mdpi.com
M Fortunato, M Ravanelli, A Mazzoni - Remote Sensing, 2019 - mdpi.com
The number of **Android** devices enabling access to **raw GNSS** (Global Navigation Satellite System) **measurements** is rapidly increasing, thanks to the dedicated Google APIs. In this study, the Xiaomi Mi8, the first **GNSS** dual-frequency smartphone embedded with the …
Related articles All 6 versions

A controlled-environment quality assessment of **android GNSS raw measurements** [PDF] mdpi.com
N Gogoi, A Minetto, N Linty, F Dovis - Electronics, 2019 - mdpi.com

Google Logging Tools: GnssLogger

- RINEX
- Sensors
- Updated UI

Google Analysis Tools

- L1,L5 analysis
- Kalman Filter positions
- ADR (carrier phase) positions
- Select satellites for position
- RINEX

Android 11, API preview

- Antenna Phase Center Offset
- C/No at Baseband and Antenna

RINEX V3 logging

Why didn't Android use RINEX in the first place?
Because there are many raw measurement attributes that are very important to phones but not present in RINEX:

Android Raw Measurement API

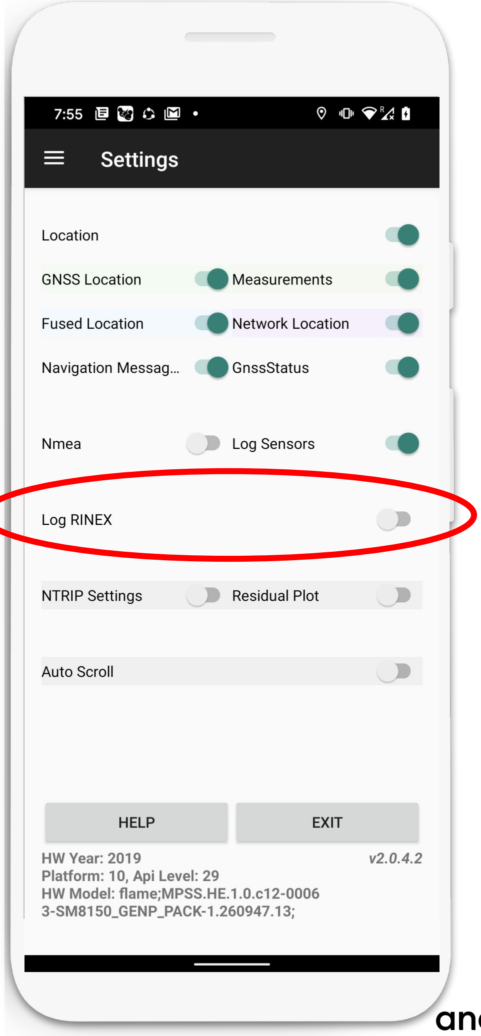
RINEX

Observation codes:
I
Q
I+Q
L1C
...

-	STATE_CODE_LOCK STATE_BIT_SYNC STATE_SYMBOL_SYNC STATE_SUBFRAME_SYNC STATE_MSEC_AMBIGUOUS STATE_TOW_DECODED
pseudorange	getReceivedSvTimeNanos
-	getReceivedSvTimeUncertaintyNanos
Doppler	getPseudorangeRateMetersPerSecond
-	getPseudorangeRateUncertaintyMetersPerSecond
Carrier phase	getAccumulatedDeltaRangeMeters
-	getAccumulatedDeltaRangeUncertaintyMeters
	...

RINEX logging feature

- New switch “Log RINEX” on settings UI.
- Logs a new file with .<yy>o extension during a logging session.



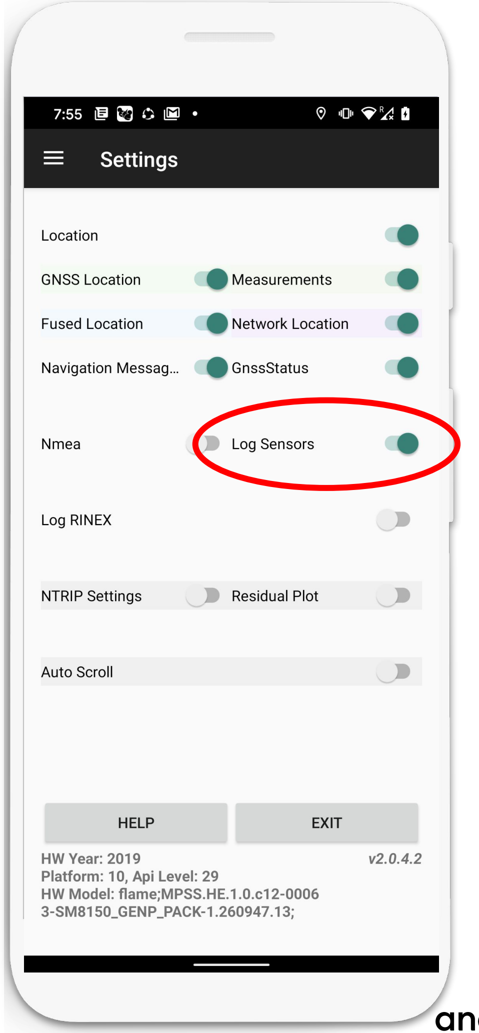
RINEX logging feature, Demo

Resulting log file

```
     3.03           OBSERVATION DATA    M                   RINEX VERSION / TYPE
GnssLogger          Google 10           20200503 231859 UTC PGM / RUN BY / DATE
G    8 C1C L1C D1C S1C C5Q L5Q D5Q S5Q                      SYS / # / OBS TYPES
R    4 C1C L1C D1C S1C                                      SYS / # / OBS TYPES
E    8 C1C L1C D1C S1C C5Q L5Q D5Q S5Q                      SYS / # / OBS TYPES
  2020     05     03     23     18   59.0000000     GPS     TIME OF FIRST OBS
 10 R03  5 R04  6 R05  1 R09 -2 R10 -7 R11  0 R16 -1 R19  3 GLONASS SLOT / FRQ #
    R20  2 R21  4                                           GLONASS SLOT / FRQ #
                                                            END OF HEADER
> 2020 05 03 23 18 59.4335010  0 22
G02  21417282.32406     73185.88506     -1719.73206        35.50006
G05  22300207.68714   -112219.85214      2621.74614        24.00014
G06  23045754.35605    134571.33005     -3128.20605        30.90005  23043405.48205     86068.24305     -2335.98805        33.80005
G12  20076248.90205     11577.90905      -282.75305        29.90005
G19  24887062.54506    123867.76306     -2892.13106        35.60006
G24  23993329.963 2                     -3204.450 2        16.900 2  23990950.810 3     77481.322 3     -2393.832 3        19.300 3
G25  20826431.26206    -73129.19806      1687.83606        38.30006  20824079.98905    -46612.94305      1260.34705        32.70005
G29  22812120.69706    -93479.05806      2167.12406        36.80006
R10  19940862.62806    -46927.57806      1112.47106        36.30006
R09  19682270.34814     87594.00214     -2123.68914        29.30014
R11  23922409.86005   -169263.44205      4069.37405        32.40005
R20  20002264.62014     -8459.13014       201.34614        23.50014
R19  21431733.520 3                     -2774.250 3        21.500 3
R21  23264768.63614   -113555.75014      2728.09314        28.20014
R03  23719630.54105     13276.33705      -365.91605        29.70005
R04  23142889.51105    -99259.64405      2378.93905        34.90005
E11  25123308.895 4                      1995.250 4        24.200 4  25121184.26614    -55072.92114      1508.33314        23.90014
E12  21587675.963 3                      -117.150 3        20.900 3  21585529.14904      3036.03304       -83.01704        23.90004
E24  21965884.83406    -22367.14406       516.71306        35.50006  21963768.30005    -14766.74205       392.67805        29.80005
E25  27186938.07405   -113069.38905      2620.40705        34.30005  27184813.14514    -74028.56014      1984.20714        27.20014
E31  24553576.413 3                     -2154.700 3        22.600 3
E33  25417906.25005     92216.04505     -2143.17905        35.20005  25415782.82004     60533.44904     -1619.75404        29.40004
> 2020 05 03 23 19 00.4335010  0 23
G02  21417597.70606     74901.99006     -1716.50206        37.30006
G05  22299699.239 3                      2623.600 3        21.900 3
G06  23046335.05405    137695.37705     -3123.89005        31.70005  23043990.97705     88401.17805     -2332.76105        34.30005
G12  20076287.27605     11857.38105      -280.86605        32.40005
G19  24887598.27406    126755.80206     -2887.63706        37.70006
```

Sensor logging feature

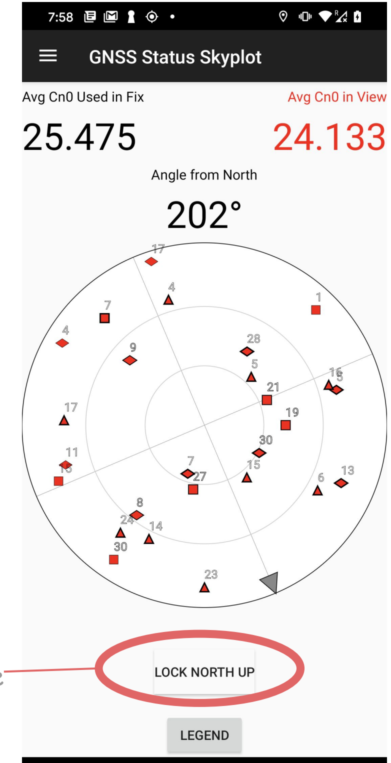
- Raw sensor data
- Accelerometer, rate-gyro, and magnetometer measurements
- In both calibrated and uncalibrated formats



UI Improvements

Skyplot

az/el plot of all satellites



Unique feature

Status

ID, C/No, az, el

ID	GNSS	Freq	C/N0	UsedInFix	Elev	Azim
5		L1	31.1	T	21.0	278.0
7		L1	30.4	T	64.0	42.0
8		L1	21.0	T	33.0	60.0
9		L1	20.6	F	40.0	154.0
11		L1	24.8	T	17.0	97.0
13		L1	22.8	T	15.0	316.0
17		L1	17.8	F	3.0	185.0
27		L1	15.0	T	10.0	36.0
28		L1	26.6	T	47.0	233.0
30		L1	38.6	T	59.0	320.0
4		L1		F	7.0	143.0
9		L5	25.6	T	40.0	154.0
30		L5	21.3	F	59.0	320.0
14		G1	29.9	T	26.0	49.0
6		G1	21.6	T	24.0	323.0
16		G1	23.4	T	24.0	275.0
15		G1	39.2	T	56.0	344.0
5		G1	35.5	T	57.0	248.0
24		G1	19.6	F	21.0	61.0
23		G1	14.2	F	8.0	23.0
17		G1	19.6	F	19.0	115.0
4		G1	21.6	T	24.0	187.0
193		J1		F	10.0	307.0
1		E1	22.1	T	9.0	247.0
7		E1	23.6	T	16.0	160.0

Google Logging Tools: GnssLogger

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Google Analysis Tools

- L1,L5 analysis
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GNSS Logger

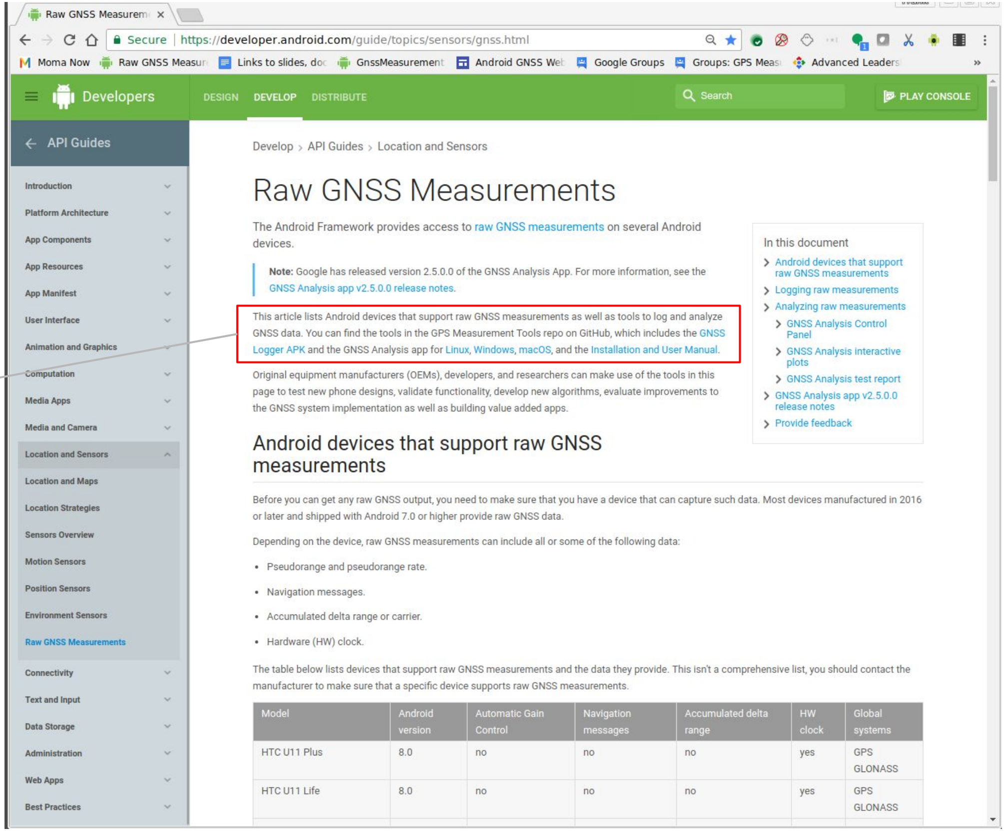
GNSS Analysis

https://g.co/GnssTools

Links to tools:

... find the tools in the GPS Measurement Tools repo on GitHub, which includes the [GNSS Logger APK](#) and the GNSS Analysis app for
- [Linux](#),
- [Windows](#),
- [macOS](#),

and the [Installation and User Manual](#).



GNSS Analysis App, v3.0.3.0

Major release, compatible with Android P and Q (aka 10)

Major feature updates (from v3.0.0.0)

Minor feature updates

Bug fixes

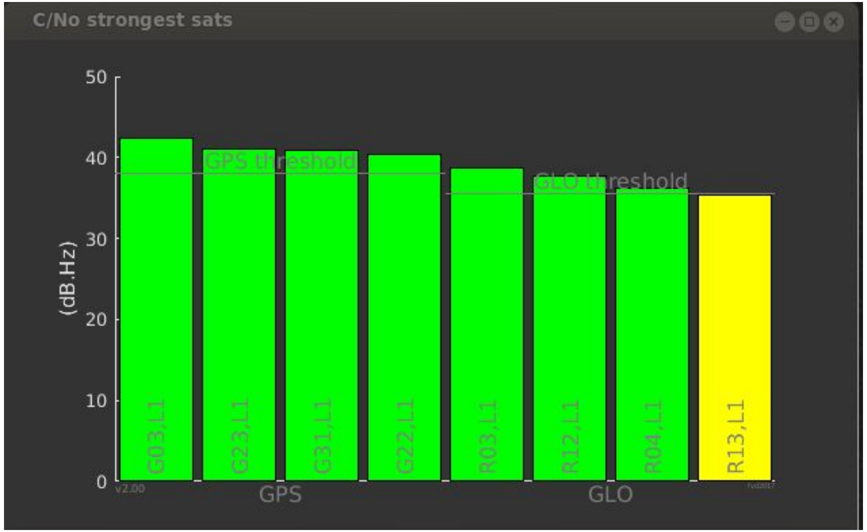
Version numbering: v3.0.3.0

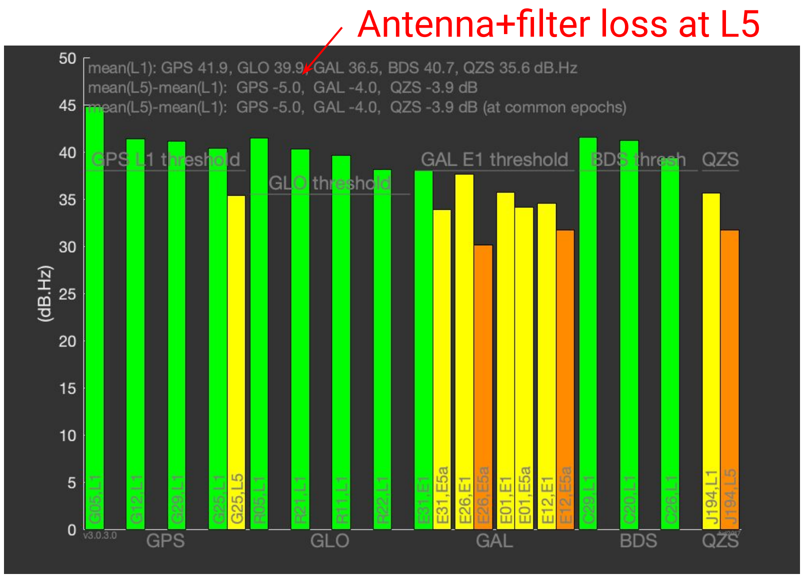
Available now: https://g.co/GnssTools

Replaces v2.6.3.0

L1L5 C/No Comparison

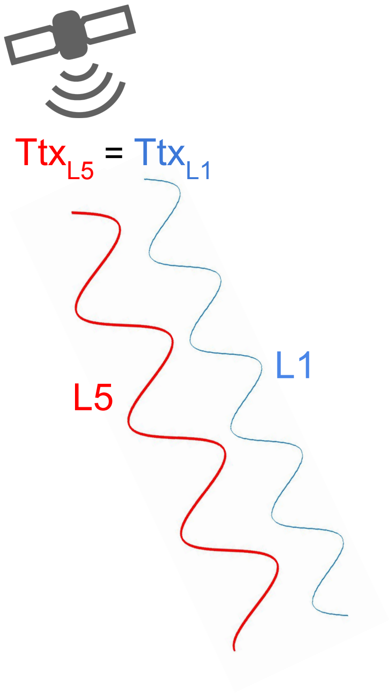
L1 Only





Minimum C/No with 0 dBi RHCP antenna with 2dB Front End Noise Figure		
	GPS (dB.Hz)	GAL (dB.Hz)
L1/E1	45.5	47
L5/E5a (I + Q)	49	49
L5/E5a (I only)	46	46

Group Delay



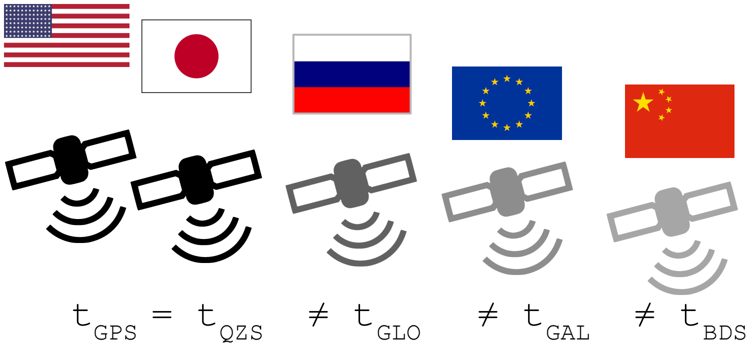
When two signals of different frequency pass through a medium (including: Earth's atmosphere, and the RF chain of the receiver), they experience different time delays relative to each other.

Also, the signal processing in different GNSS chips might result in significant differences in L1 v L5 delays, and this must be measured and compensated for before using L1 and L5 measurements together.

Observed $Ttx_{L5} \neq$ Observed Ttx_{L1}

i.e. $Pseudorange_{L5} \neq Pseudorange_{L1}$

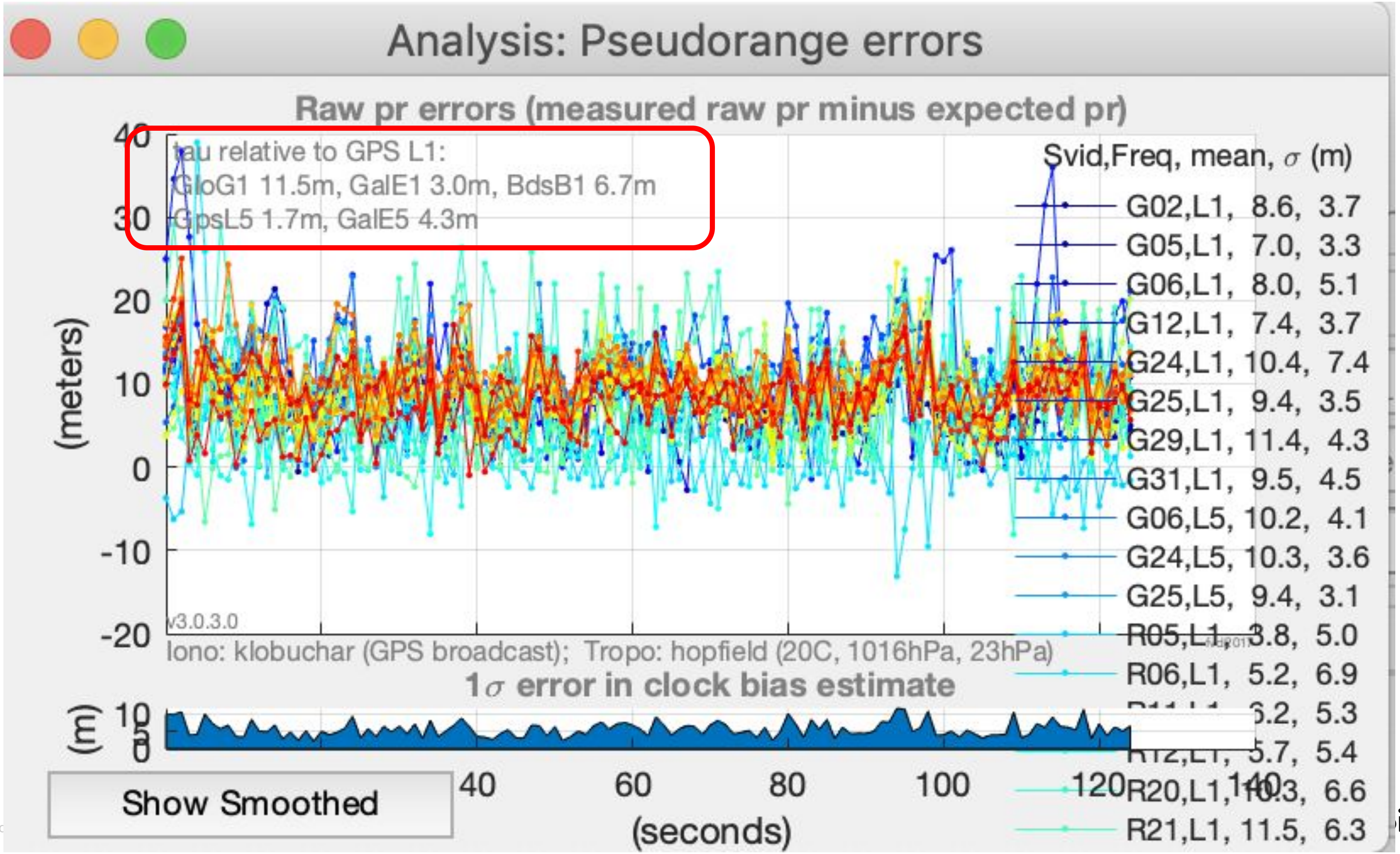
Inter System Bias



The different GNSSes are synced to different times (except QZS which manages to be synced to GPS)

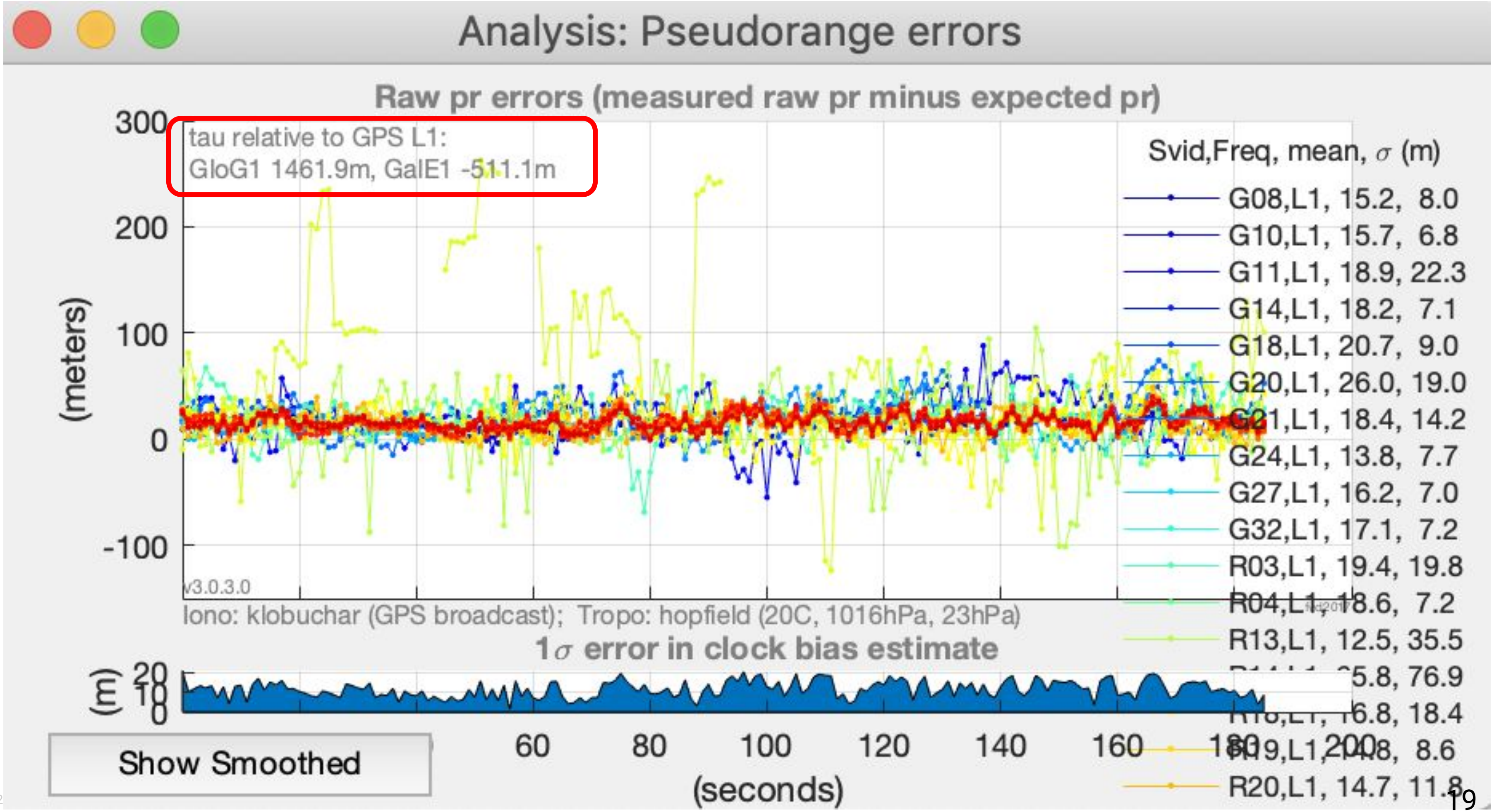
Moreover, different GPS receivers will treat different signal types differently, resulting in further differences in observed times. These offsets must be measured and accounted for before combining pseudoranges from different systems.

Example 1:



Analysis: Pseudorange errors
Raw pr errors (measured raw pr minus expected pr)
tau relative to GPS L1:
GloG1 11.5m, GalE1 3.0m, BdsB1 6.7m
GpsL5 1.7m, GalE5 4.3m
Svid,Freq, mean, σ (m)
G02,L1, 8.6, 3.7
G05,L1, 7.0, 3.3
G06,L1, 8.0, 5.1
G12,L1, 7.4, 3.7
G24,L1, 10.4, 7.4
G25,L1, 9.4, 3.5
G29,L1, 11.4, 4.3
G31,L1, 9.5, 4.5
G06,L5, 10.2, 4.1
G24,L5, 10.3, 3.6
G25,L5, 9.4, 3.1
R05,L1, 3.8, 5.0
R06,L1, 5.2, 6.9
R20,L1, 10.3, 6.6
R21,L1, 11.5, 6.3
(meters)
40
30
20
10
0
-10
-20
v3.0.3.0
Iono: klobuchar (GPS broadcast); Tropo: hopfield (20C, 1016hPa, 23hPa)
1σ error in clock bias estimate
(m)
10
5
0
Show Smoothed
40
60
80
100
120
140
(seconds)

Example 2:



Analysis: Pseudorange errors
Raw pr errors (measured raw pr minus expected pr)
tau relative to GPS L1:
GloG1 1461.9m, GalE1 -511.1m
300
200
100
0
-100
(meters)
v3.0.3.0
Svid,Freq, mean, σ (m)
G08,L1, 15.2, 8.0
G10,L1, 15.7, 6.8
G11,L1, 18.9, 22.3
G14,L1, 18.2, 7.1
G18,L1, 20.7, 9.0
G20,L1, 26.0, 19.0
G21,L1, 18.4, 14.2
G24,L1, 13.8, 7.7
G27,L1, 16.2, 7.0
G32,L1, 17.1, 7.2
R03,L1, 19.4, 19.8
R04,L1, 18.6, 7.2
R13,L1, 12.5, 35.5
R20,L1, 14.7, 11.8
Iono: klobuchar (GPS broadcast); Tropo: hopfield (20C, 1016hPa, 23hPa)
1σ error in clock bias estimate
(m)
20
10
0
Show Smoothed
60
80
100
120
140
160
(seconds)

Raw pseudorange, Kalman Filter, Carrier Phase (ADR)

Result with PPK (Post-Processed-Kinematic)

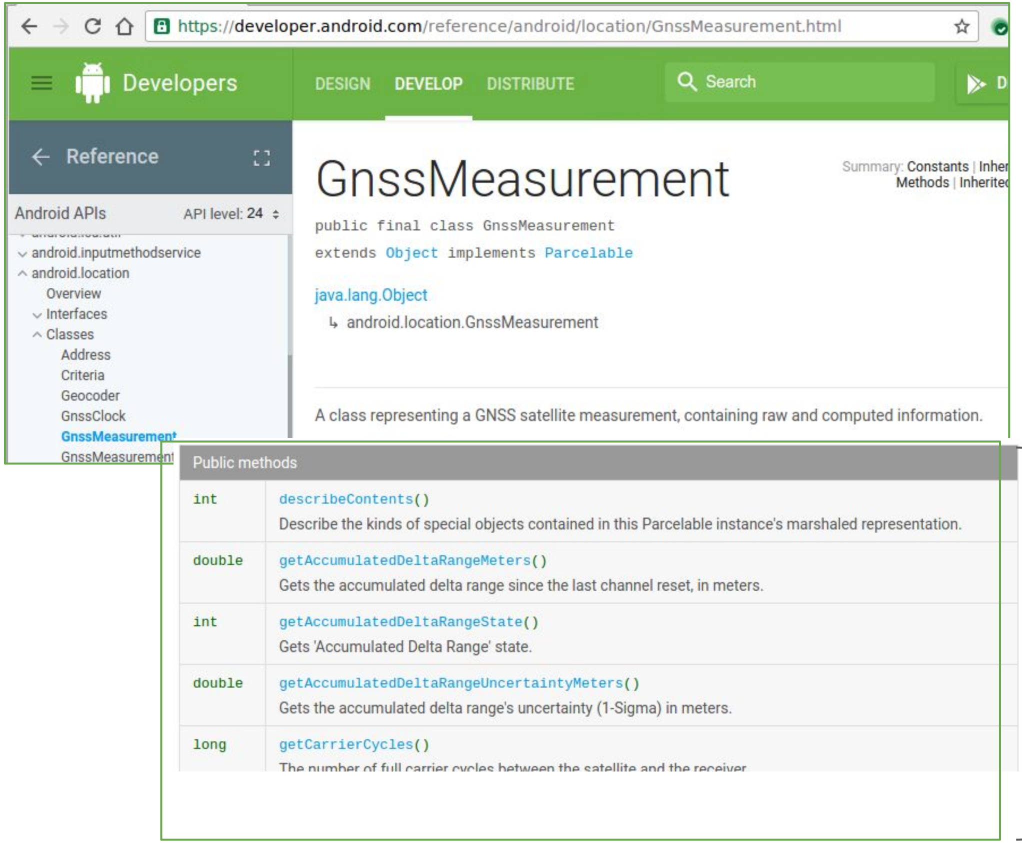
Raw pseudorange, Kalman Filter, ADR

Comparison of positions from the same data set, left to right:

- Raw Pseudorange, processed with Weighted Least Squares (weighted by reported measurement uncertainty).
- Kalman Filter, using WLS position, and WLS velocity (velocity computed from Doppler measurements)
  Not shown: WLS position from smoothed pseudorange, is similar to Kalman Filter position.
- WLS position from ADR (Carrier Phase).

Conclusion: you should expect to get noisy positions from *Raw* Pseudoranges.

Carrier Phase



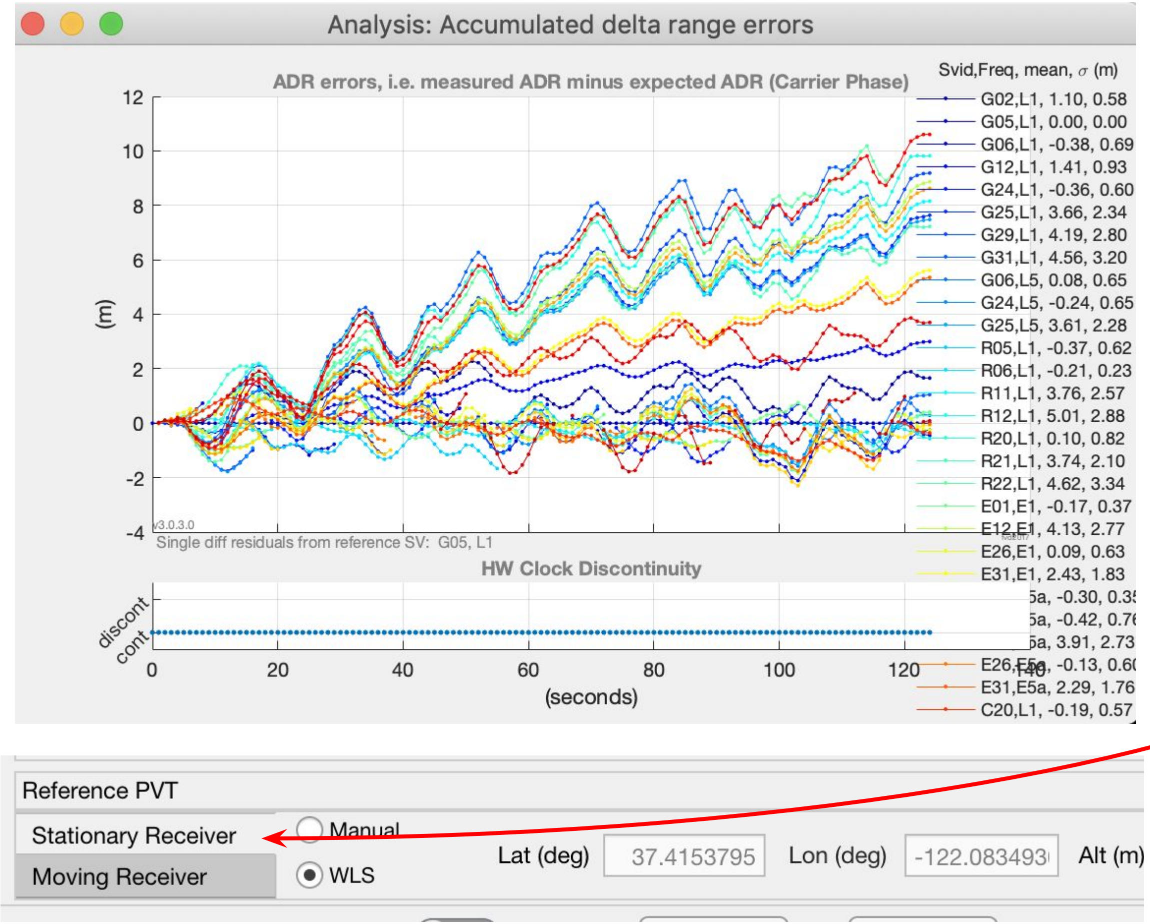
Public methods

int	describeContents() Describe the kinds of special objects contained in this Parcelable instance's marshaled representation.
double	getAccumulatedDeltaRangeMeters() Gets the accumulated delta range since the last channel reset, in meters.
int	getAccumulatedDeltaRangeState() Gets 'Accumulated Delta Range' state.
double	getAccumulatedDeltaRangeUncertaintyMeters() Gets the accumulated delta range's uncertainty (1-Sigma) in meters.
long	getCarrierCycles() The number of full carrier cycles between the satellite and the receiver

Public methods

getAccumulatedDeltaRangeMeters()
getAccumulatedDeltaRangeState()
getAccumulatedDeltaRangeUncertaintyMeters()
getCarrierFrequencyHz()
getCn0DbHz()
getConstellationType()
getMultipathIndicator()
getPseudorangeRateMetersPerSecond()
getPseudorangeRateUncertaintyMetersPerSecond()
getReceivedSvTimeNanos()
getReceivedSvTimeUncertaintyNanos()
getSnrInDb()
getState()
getSvid()
getTimeOffsetNanos()
hasCarrierFrequencyHz()
hasSnrInDb()


Analysis: C/No strongest sats
Analysis: Full Pseudoranges
Pseudoranges vs time
HW Clock Discontinuity
Analysis: Positions
WLS relative position from ADR (Carrier Phase)
Computed using: GPS GLO GAL BDS
Num pos fixes: 124
Show Raw
Show KalmanFilter
Analysis: C/No all sats
C/No in dB.Hz
Analysis: Clock bias
Clock bias, from: raw pr & ref pvt (blue), device (green)
1σ error in clock bias estimate; continuous (blue), discontinuous (red)
Raw pr errors (measured raw pr minus expected pr)
Show Smoothed
Analysis: Skyplot
Interval = [2019/08/15 17:46:00]UTC: +3 mins
Analysis: Clock frequency drift
Frequency drift while clock is continuous
1σ error in clock freq estimate; continuous (blue)
Analysis: Accumulated delta range errors
ADR errors, i.e. measured ADR minus expected ADR (Carrier Phase)
HW Clock Discontinuity

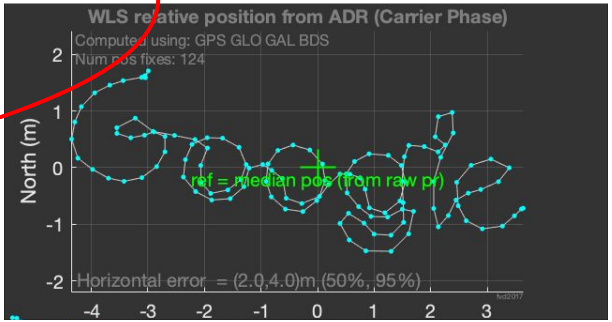


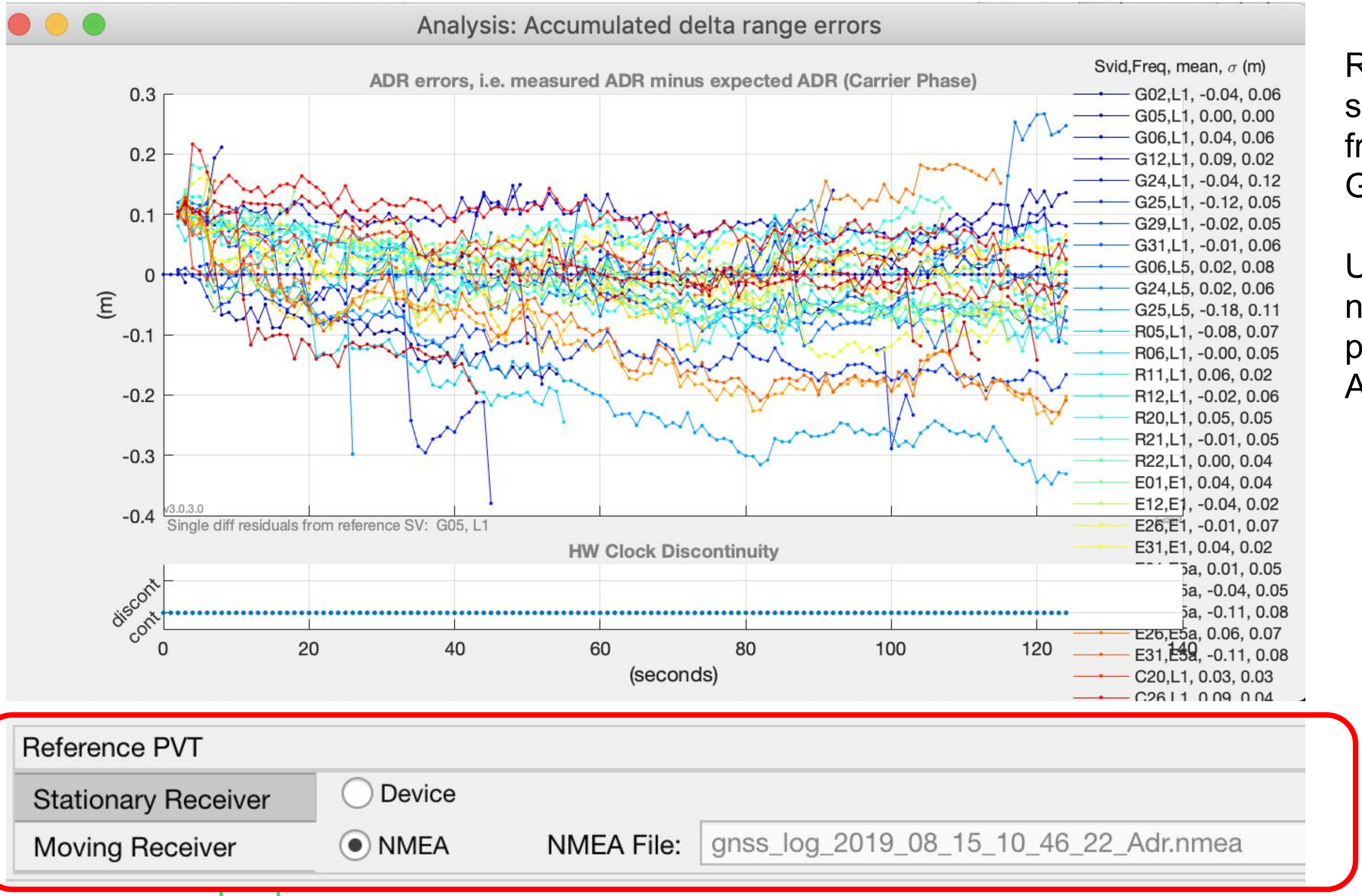
Residual errors, single-differenced from reference SV G05 L1.

Using Reference PVT specified by user, in this case “Stationary Receiver, WLS median position”.

QUESTION: Why are these residual errors growing over time?

Hint:

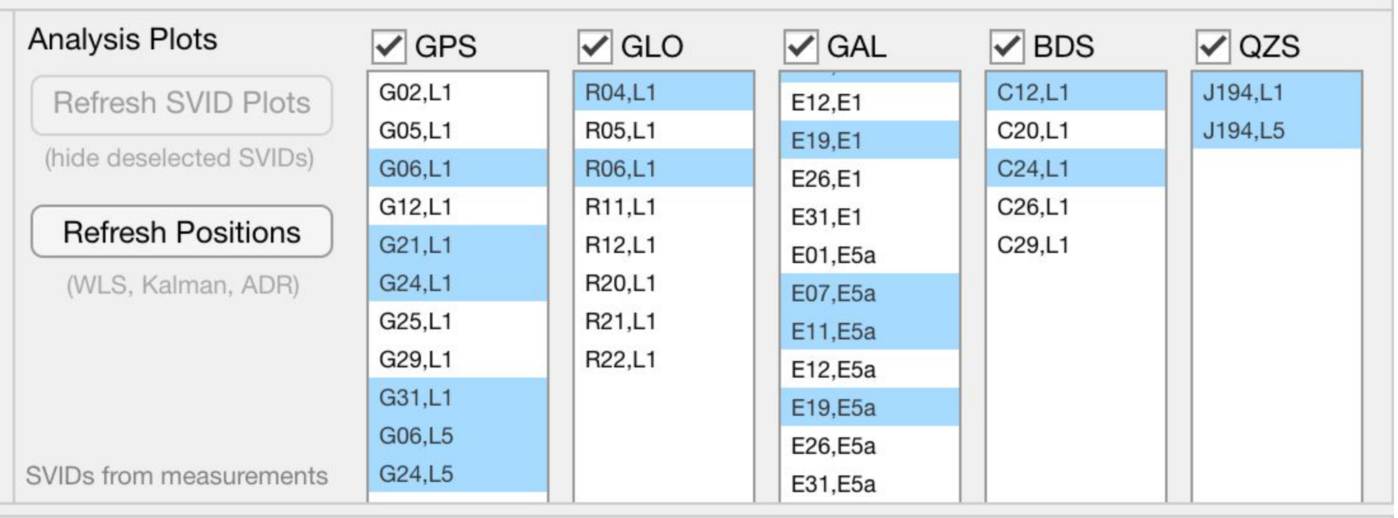




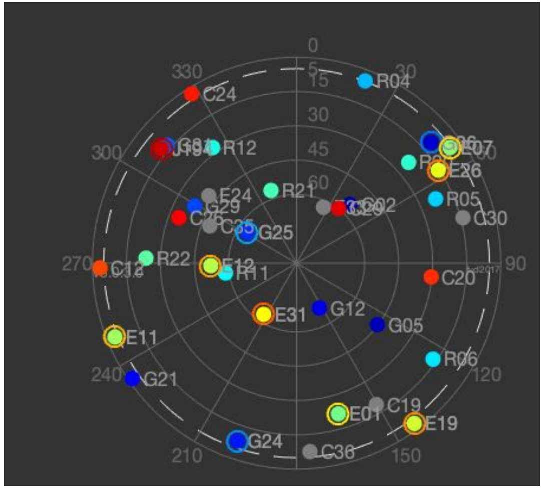
Residual errors, single-differenced from reference SV G05 L1.

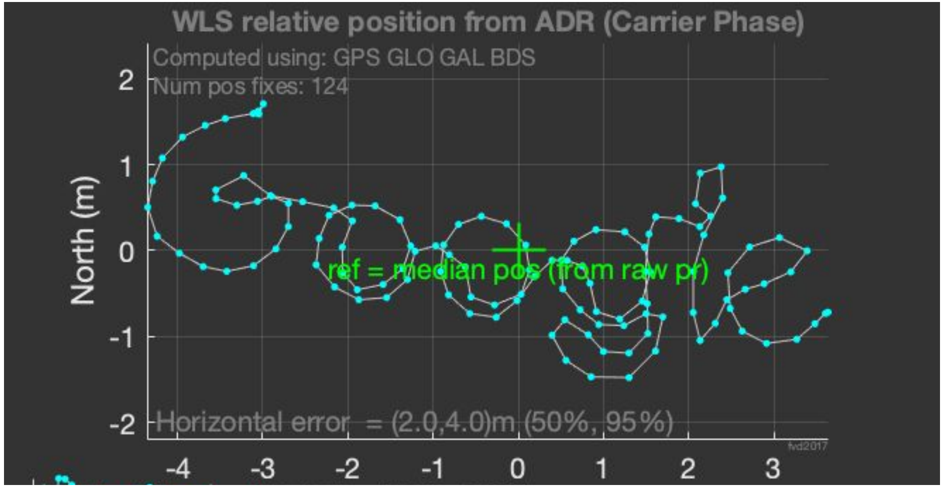
Using Reference PVT: nmea file from previously computed ADR position

Select satellites for position

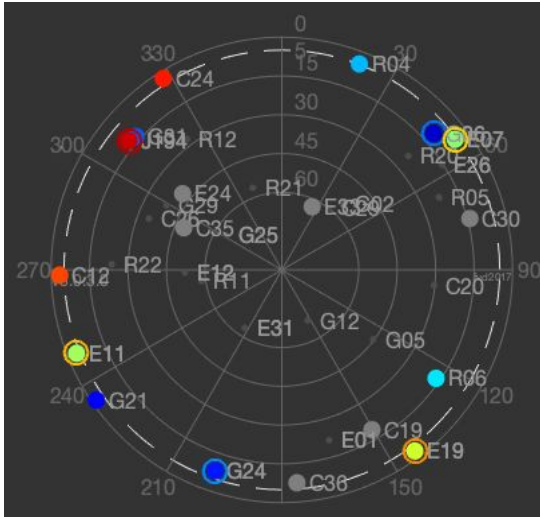


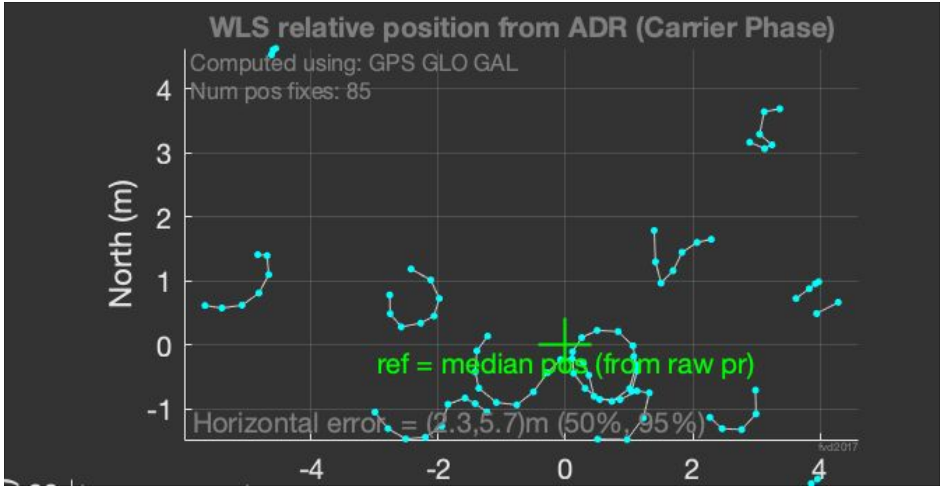
Suppose you wanted to remove all satellites *above* 30 degrees elevation. What would the position look like?





WLS relative position from ADR (Carrier Phase)
Computed using: GPS GLO GAL BDS
Num pos fixes: 124
ref = median pos (from raw pr)
Horizontal error = (2.0,4.0)m (50%, 95%)
North (m)





WLS relative position from ADR (Carrier Phase)
Computed using: GPS GLO GAL
Num pos fixes: 85
ref = median pos (from raw pr)
Horizontal error = (2.3,5.7)m (50%, 95%)
North (m)

Google Logging Tools: GnssLogger

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- Updated UI

Google Analysis Tools

- L1,L5 analysis
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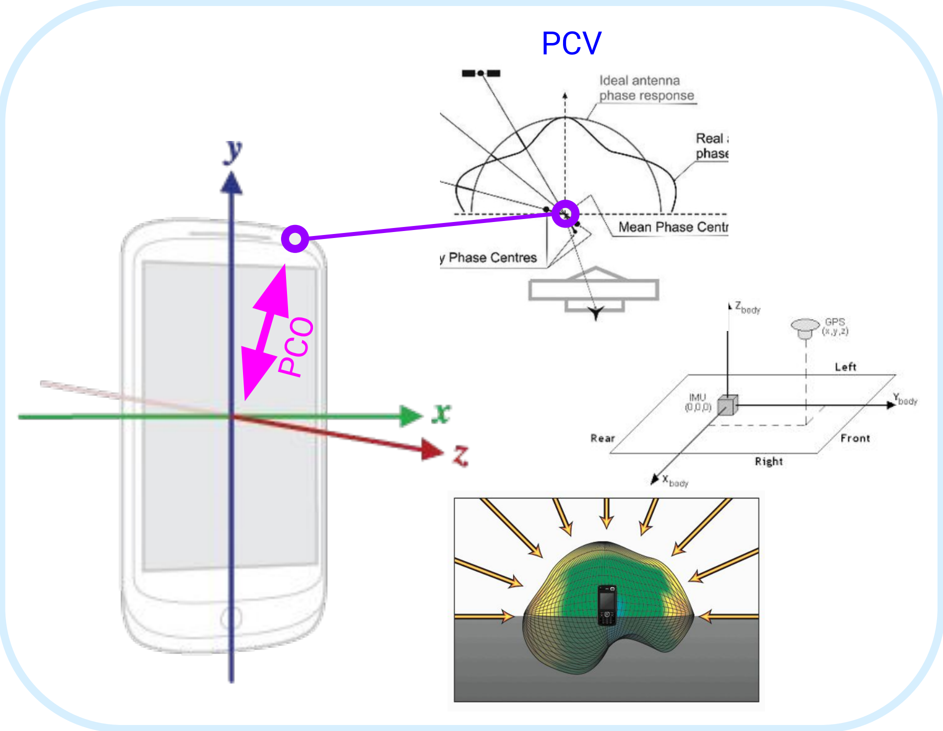
Android 11, Raw Measurements and GNSS Status API preview

- Antenna Phase Center Offset
- C/No at Baseband and Antenna

GnssAntennaInfo

New, optional antenna information

- Phase center offset (PCO)
  - Enables cm-level location
  - Useful for lever-arm offset in Android Auto
- Phase center variation (PCV)
  - Enables cm-level location
- Gain pattern
  - Improves GNSS C/N_0 based location information
- Different values by frequency, and device state



see: https://developer.android.com/reference/android/location/GnssAntennaInfo

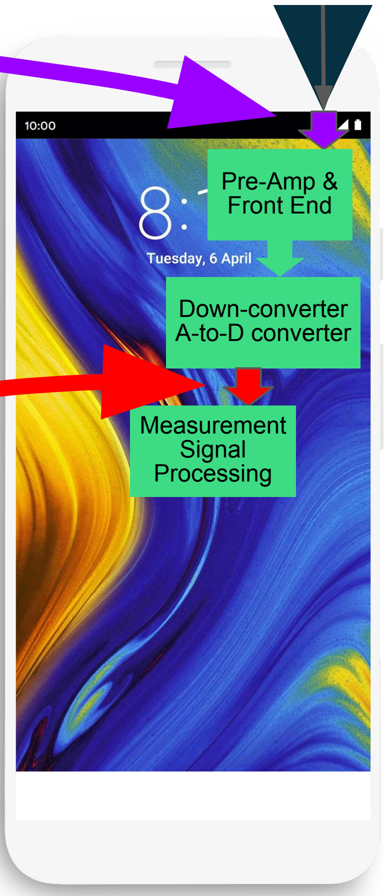
GnssStatus

Since N, GnssMeasurement and GnssSvInfo APIs require Antenna C/N_0

- For example, `getCn0DbHz()`
  - The value contains the measured C/N_0 for the signal at the antenna input
- For developers
  - More indicative of external RF; easier to externally test

Several OEMs and vendors also want Baseband C/N_0

- More directly measurable inside GNSS chipset
  - Useful in OEM and vendor device testing
- Android 11 adds basebandCn0DbHz



see: https://developer.android.com/reference/android/location/GnssStatus

Summary and Timeline

Android 11

GnssLogger

RINEX logging
Sensor logging
Updated UI

Q3 2019 ... Q1 2020 Q2 2020 Q3 2020 Q4 2020

Analysis Tools v3.0.3.0

L1L5 Analysis
Kalman Filter and ADR (Carrier Phase) processing
Satellite Selection

Analysis Tools v4.0.0.0

Read RINEX

the end. Thank You!