

2009 International Symposium on GPS/GNSS

Effect of Quasi Zenith Satellite (QZS) on GPS Positioning



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QZSS (1)

- **QZSS (Quasi-Zenith Satellite System)**
 - Regional space-based PNT system around Japan
 - First satellite launch: 2010 summer
 - 3-satellites in Phase 2
 - Interoperability with GPS
- **Satellite Orbit Characteristics**
 - IGSO (Inclined Geostationary Orbit) with slight eccentricity
 - 8 shape of satellite ground track
 - At least 1 satellite at higher-elev. angle than 70° at Tokyo
 - Effective in urban canyon or at mountainous location

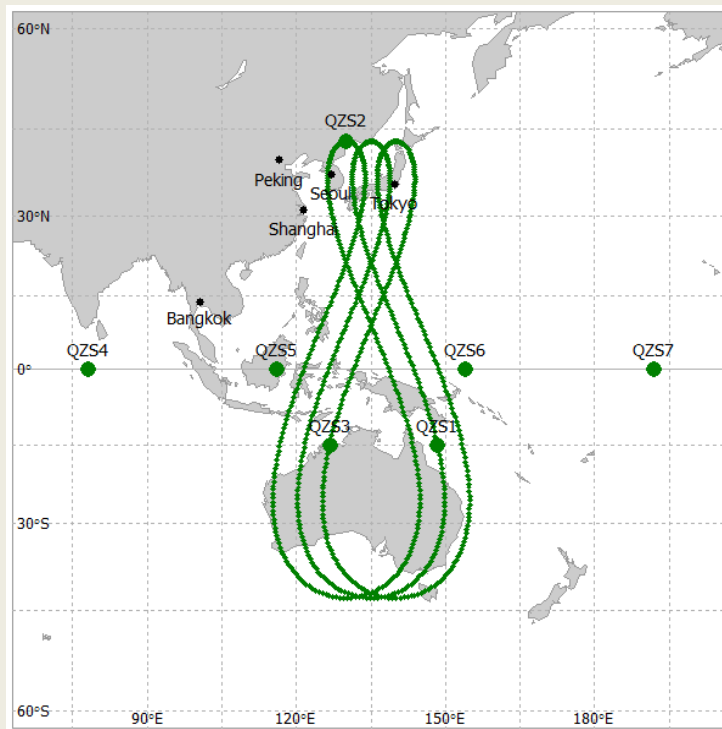
QZSS (2)

- **Expected Effects of QZSS on GPS Positioning**
 - Improved satellite availability
 - Improved satellite geometry (DOP) especially on limited sky-view condition
 - Improved accuracy for single point positioning
 - Improved integer ambiguity resolution for RTK with triple-frequency signals (L1+L2+L5)
- **DGPS corrections provided by QZSS**
 - ⇒ Out of scope of this study

Satellite Constellation

- 3 QZSs: 3 IGSO
- 7 QZSs: 3 IGSO + 4 GEO (Future Enhancement)

Ground Tracks



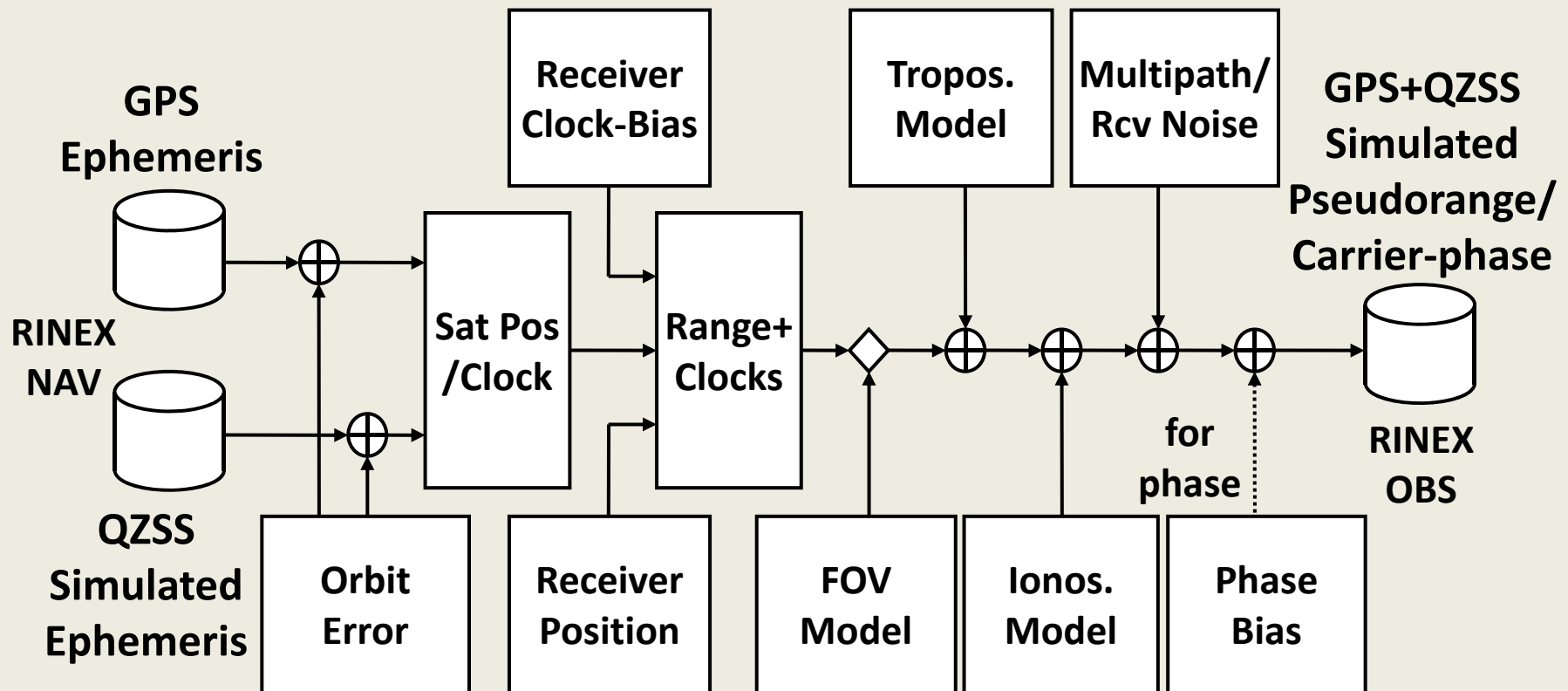
Orbit Elements

Sat	Orbit	Orbit Element			
		a (km)	e	i (°)	Center Long.
QZS1	IGSO	42164	0.075	43.0	130°E
QZS2	IGSO	42164	0.075	43.0	135°E
QZS3	IGSO	42164	0.075	43.0	140°E
QZS4	GEO	42164	0.0	0.0	78°E
QZS5	GEO	42164	0.0	0.0	116°E
QZS6	GEO	42164	0.0	0.0	154°E
QZS7	GEO	42164	0.0	0.0	168°W

Evaluation Method

- **Software Simulator**
 - Simulated (QZSS) and real (GPS) ephemerides
 - Various error models
 - Outputs RINEX OBS including GPS and QZSS data
- **Post processing analysis**
 - Inputs RINEX OBS/NAV file
 - Analysis of satellite visibility, DOP etc.
 - Various positioning modes and options

Software Simulator

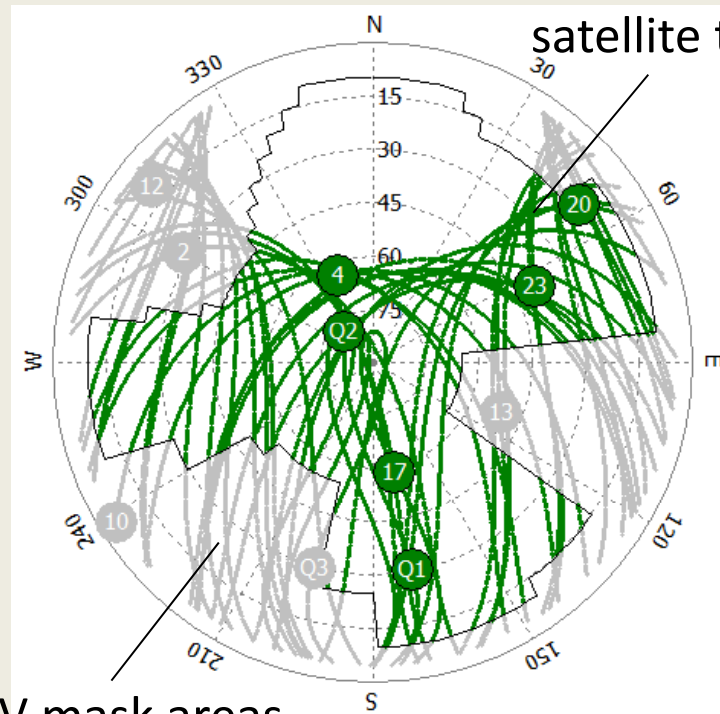


FOV Mask Model

- Simulation of typical urban canyon environment
- Limited sky-view by surrounding obstacles



Sky-view by fish-eye lens

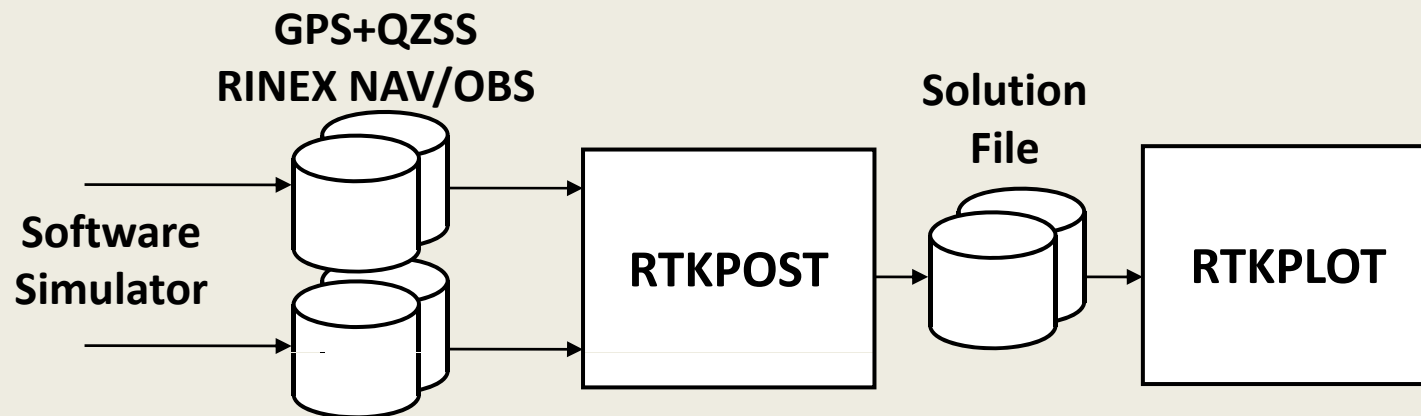


FOV mask areas

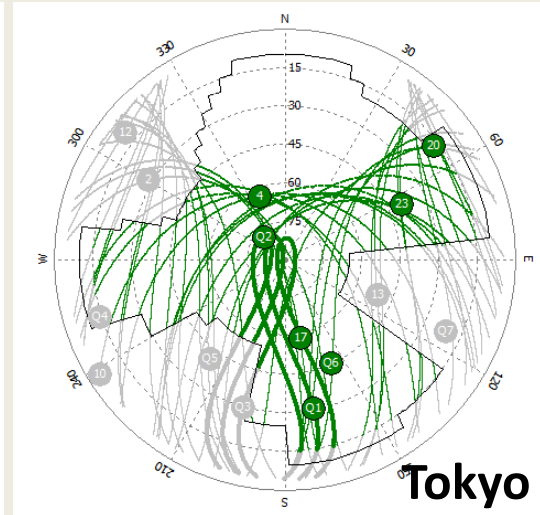
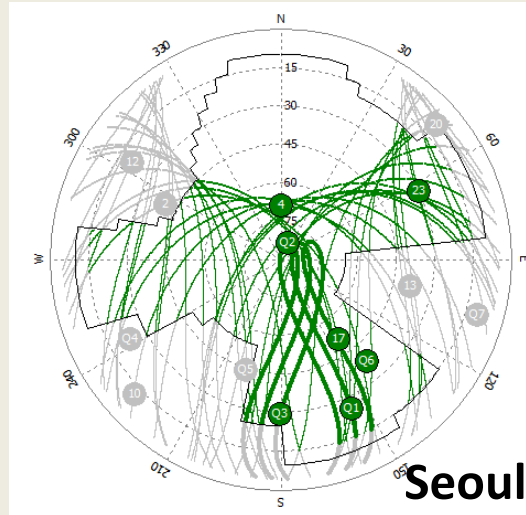
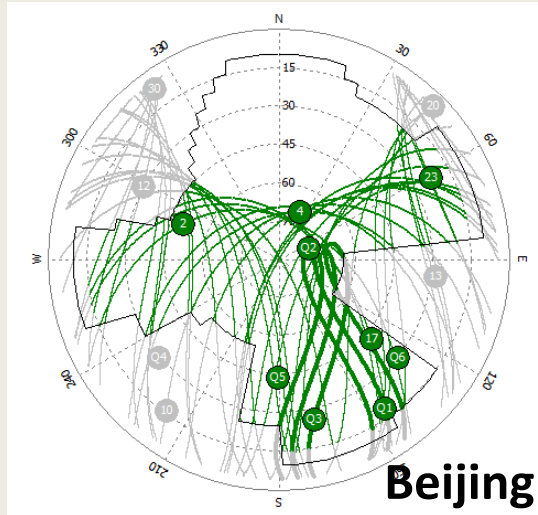
Post Processing Analysis

- **RTKLIB ver. 2.3.0b**

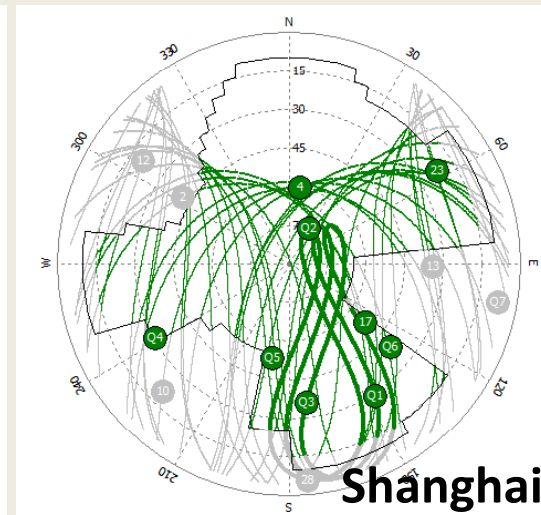
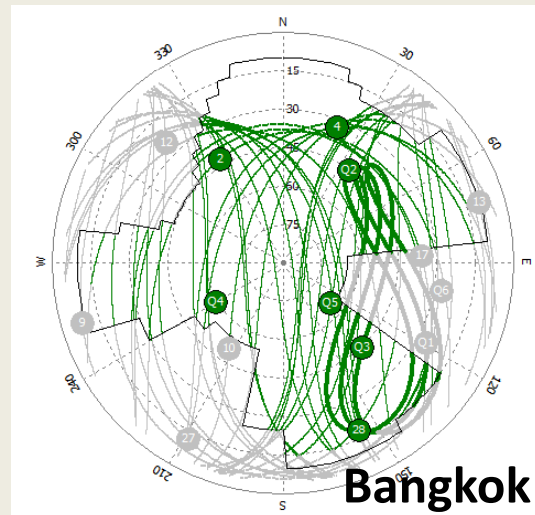
- Analysis of solution availability and DOP
- Single point positioning
- Carrier-based relative positioning to simulate RTK
- Enhancement to support QZSS RINEX OBS/NAV



Sky-Plots

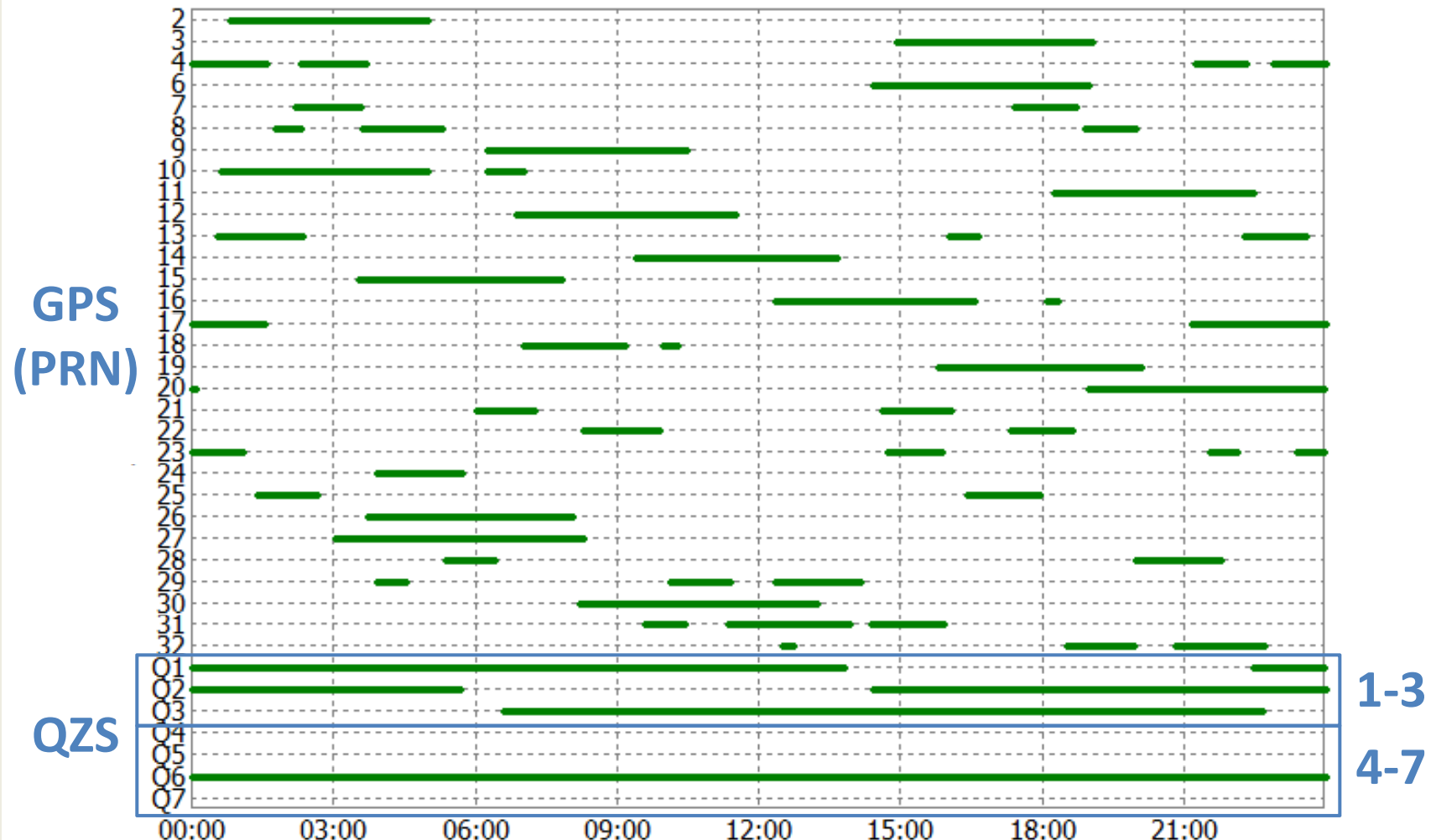


— : GPS
— : QZSS



Satellite Visibility

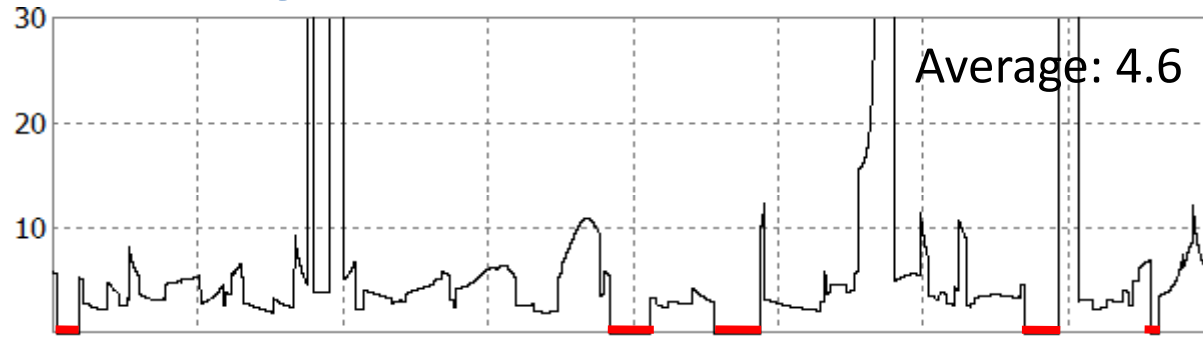
At Tokyo with FOV mask



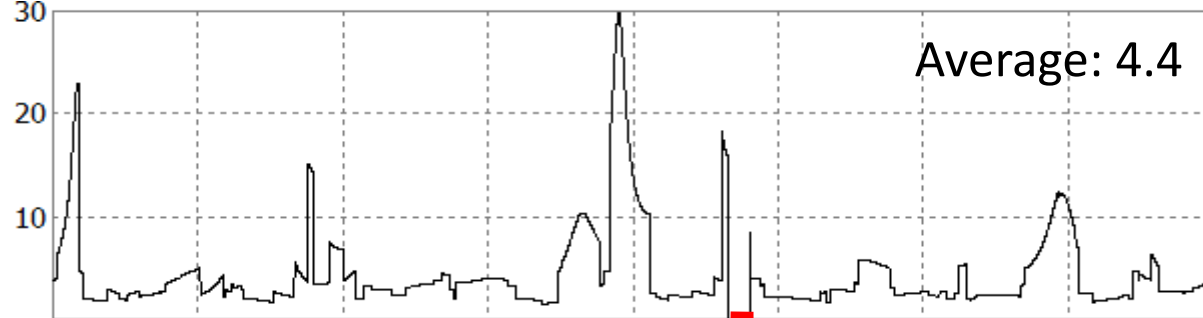
PDOP

At Tokyo with FOV mask

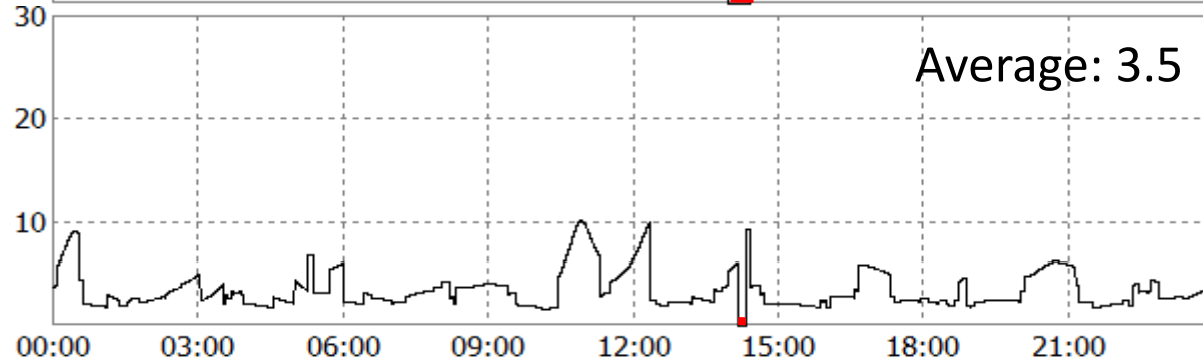
GPS Only



GPS+3 QZSs



GPS+7 QZSs



— : # of Sats<4

Solution Availability and PDOP

Site	GPS Only		GPS+3 QZSs		GPS+7 QZSs	
	Ratio*	Average PDOP	Ratio*	Average PDOP	Ratio*	Average PDOP
Tokyo	82.2%	4.6	98.1%	4.4	99.2%	3.5
Seoul	75.7%	4.9	98.5%	4.2	100%	3.3
Beijing	83.5%	5.5	96.6%	4.2	100%	2.9
Shanghai	78.6%	5.2	95.3%	4.1	100%	2.3
Bangkok	90.3%	4.5	98.8%	3.2	100%	2.5

* Ratio of epochs with proper positioning solutions

Single Point Positioning

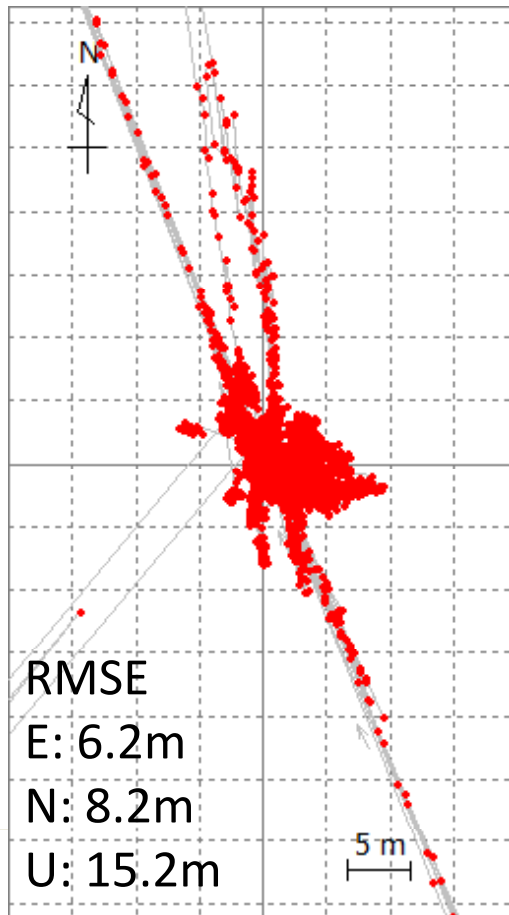
- **Positioning Options**

- Mode: Single point positioning
- GPS+QZSS, L1 C/A, pseudorange
- Elevation mask: 15°
- Ionosphere correction: Klobuchar model
- Troposphere correction: Saastamoinen model
- No DGPS correction

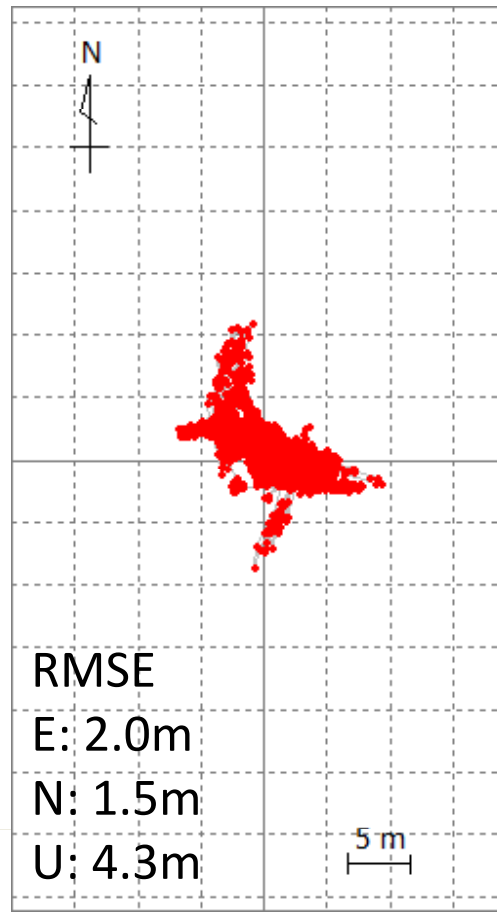
Solutions of Single Point Pos.

At Tokyo with FOV mask

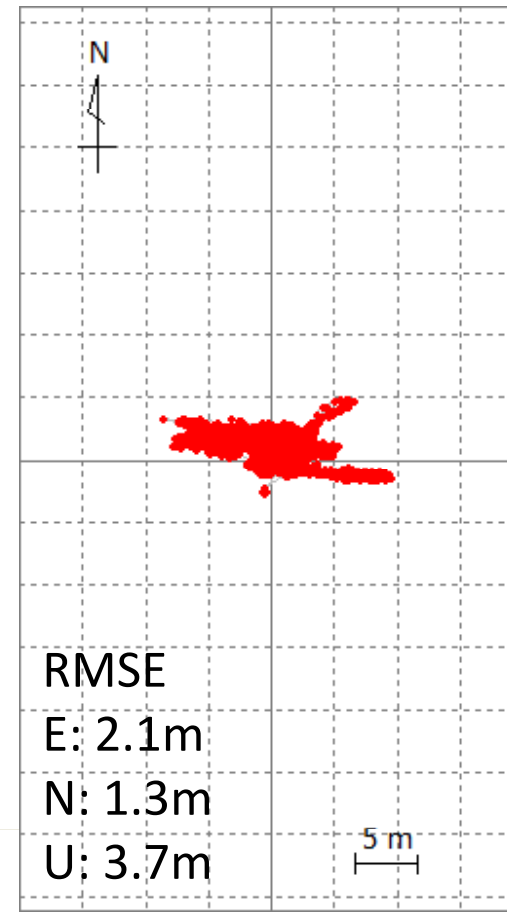
GPS Only



GPS+3 QZSs



GPS+7 QZSs



Accuracy of Single Point Pos.

RMS Errors (m)

Site	GPS Only			GPS+3 QZSs			GPS+7 QZSs		
	EW	NS	UD	EW	NS	UD	EW	NS	UD
Tokyo	6.2	8.1	15.2	2.0	1.5	4.3	2.1	1.3	3.7
Seoul	5.0	5.4	17.5	1.8	1.4	4.1	1.8	1.4	4.1
Beijing	5.7	5.4	11.1	1.3	1.3	3.1	1.4	2.0	3.6
Shanghai	3.5	3.2	8.3	2.8	2.4	6.0	1.1	1.4	2.8
Bangkok	1.8	2.0	6.8	1.2	1.8	3.6	1.2	0.7	5.0

RTK Positioning

- **Positioning Options**

- Mode: Kinematic
- GPS+QZSS, L1+L2+L5, pseudorange+carrier-phase (assume only 4 GPS satellites support L5)
- Elevation mask: 15°
- Ionosphere/troposphere correction: None
- Integer ambiguity resolution: LAMBDA (thres.=3)

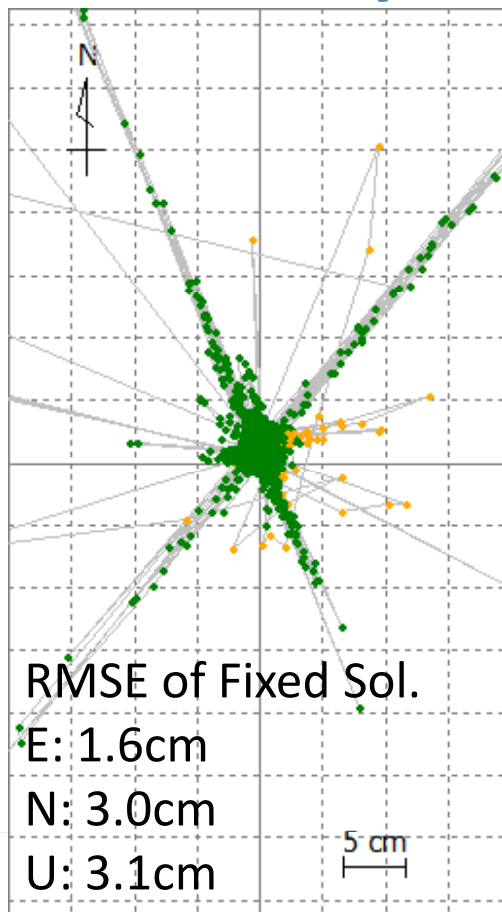
- **Baseline Length: 10 km**

- Rover relative position with refer to base-station

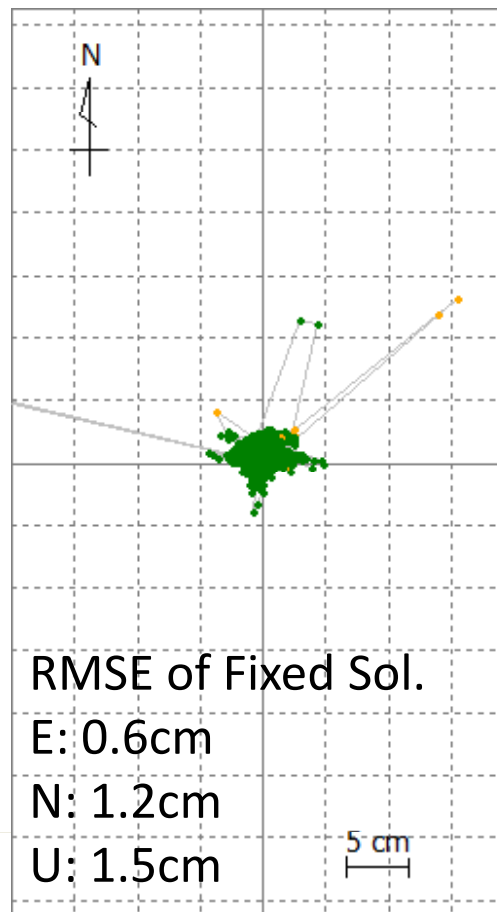
Solutions of RTK Positioning

At Tokyo with FOV mask

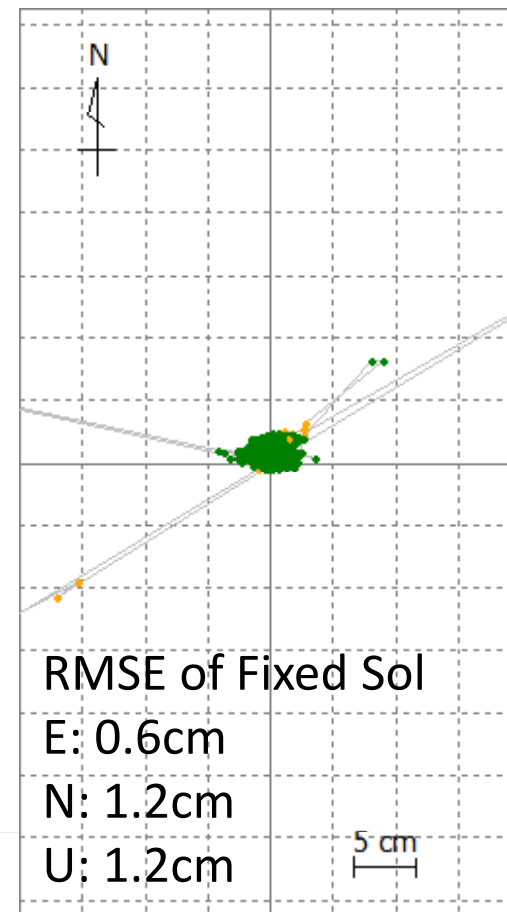
GPS Only



GPS+3 QZSs



GPS+7 QZSs



● : Fixed Solution ● : Float Solution

Accuracy of RTK Positioning

Fixing Ratio and RMS Errors (cm) of Fixed Sol.

Site	GPS Only			GPS+3 QZSs			GPS+7 QZSs		
	Fixing Ratio			Fixing Ratio			Fixing Ratio		
	EW	NS	UD	EW	NS	UD	EW	NS	UD
Tokyo	84.2%			97.5%			98.5%		
	1.6	3.0	3.1	0.6	1.2	1.5	0.6	1.2	1.2
Seoul	76.0%			98.6%			99.1%		
	0.9	2.0	3.3	0.6	1.4	1.7	0.5	1.4	1.0
Beijing	86.4%			95.6%			98.8%		
	1.2	2.0	2.9	0.4	1.6	1.2	0.3	1.5	1.0
Shanghai	76.7%			98.5%			98.2%		
	0.9	1.9	2.3	0.5	1.5	1.0	0.2	1.4	0.7
Bangkok	83.5%			95.6%			96.4%		
	0.8	2.7	2.1	0.4	2.6	1.8	0.2	2.5	1.3

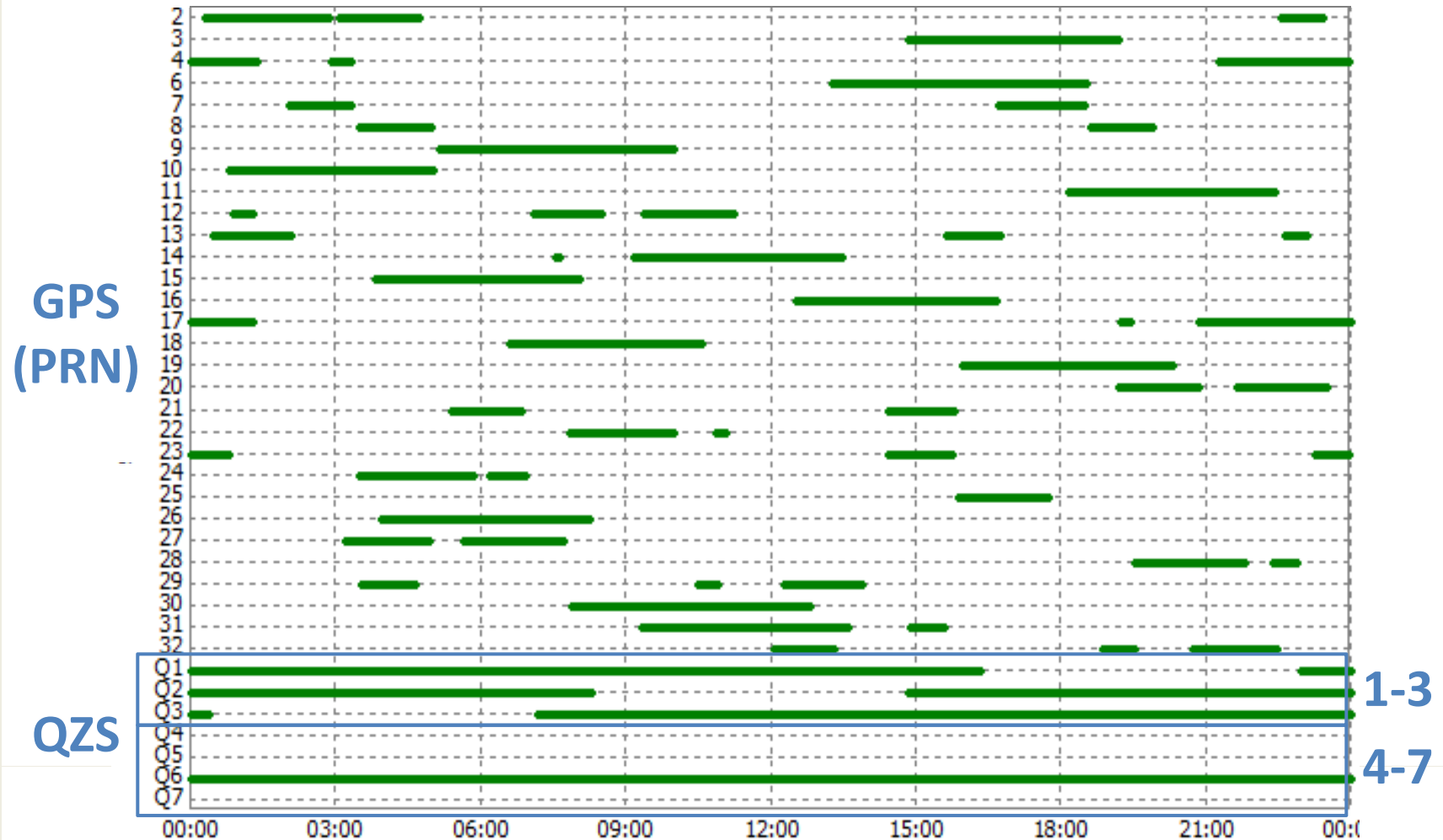
Conclusions

- **Evaluation of the effects of QZSS on GPS positioning**
 - More than 95% of solution availability with QZSS even on limited sky-view condition
 - More accurate single point solution primary due to DOP improvement with QZSS
 - More than 90% of fixing ratio is expected for RTK with QZSS and triple-frequency signals
- **QZSS combined with GPS will much enhance the positioning performance especially in sever environment like urban canyon.**

Appendix

Satellite Visibility at Seoul

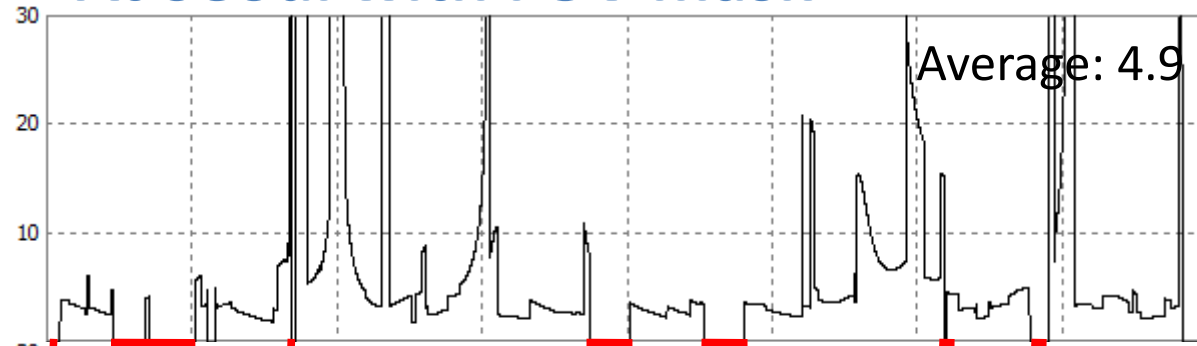
At Seoul with FOV mask



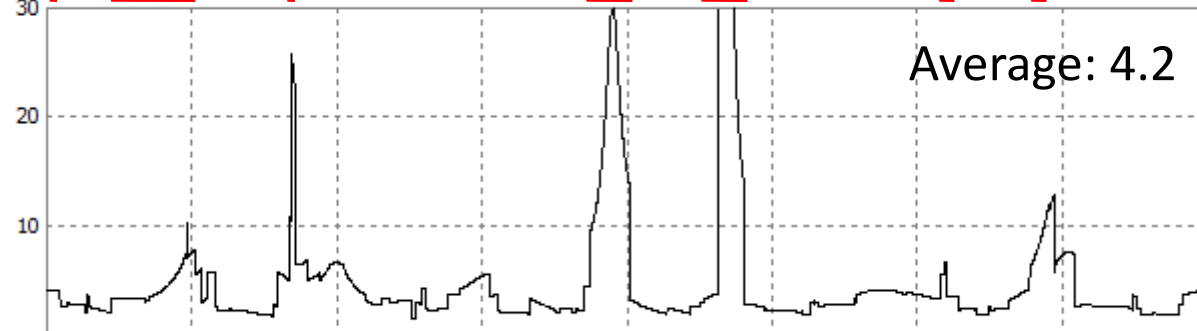
PDOP at Seoul

At Seoul with FOV mask

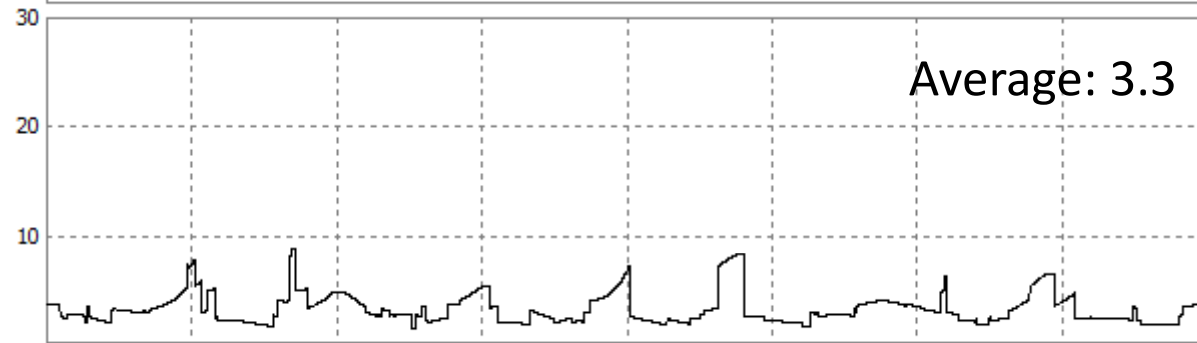
GPS Only



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