



*Multisystem GNSS receivers for High precision applications with using global high-precision service*

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Topcon Positioning Systems

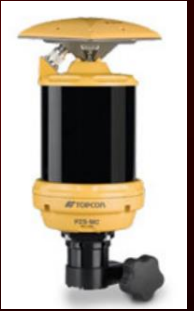
Global Navigation Satellite Systems (ICG) PPP Workshop  
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## Full Spectrum GNSS Technology Provider

- In-house development of all core GNSS technology
- Multi-constellation ASIC development  
*4<sup>th</sup> generation multi-core designs are currently in production*
- Precision mobile and infrastructure antennas
- Full range of OEM and application-specific receivers that cover all GNSS frequencies
- Leading-edge tracking, navigation, fusion, and network algorithm development







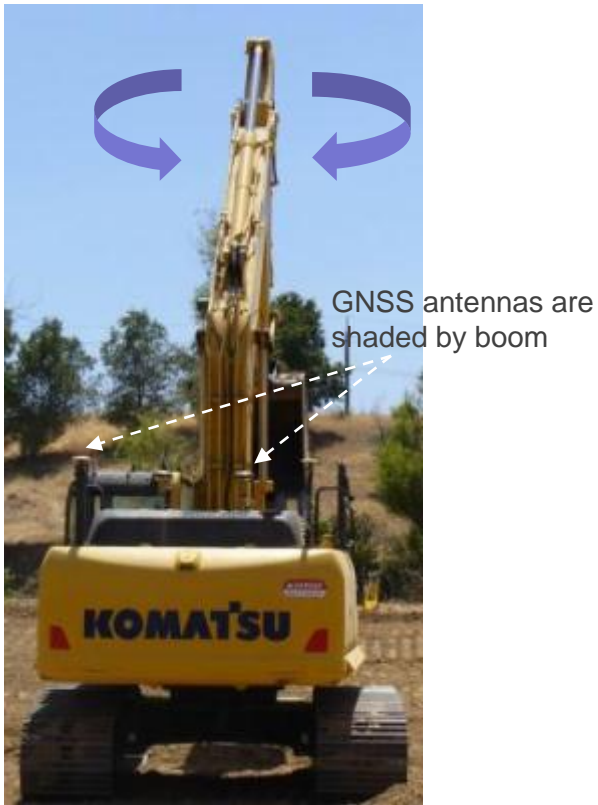
# *Area of High Precision GNSS Application – Controlling Excavator*



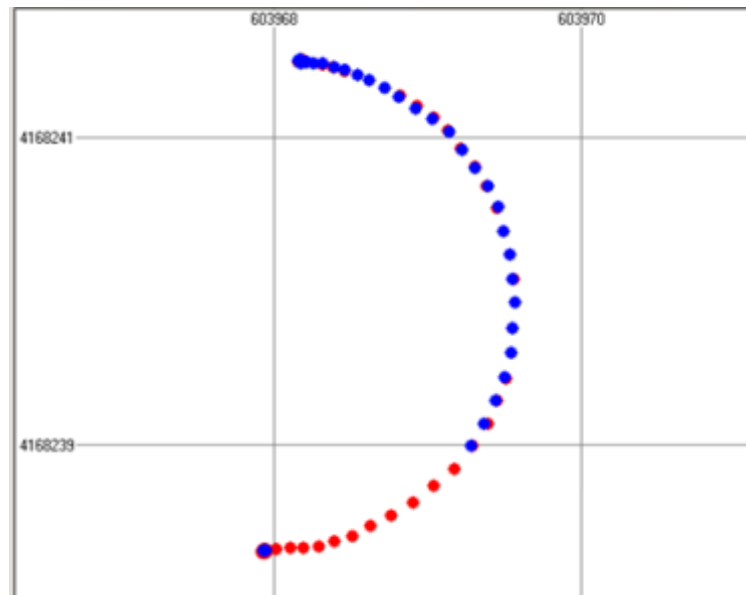
**Horizontal accuracy shall be better 10 cm**



# Multi GNSS. Excavator



- Excavator control w/ RTK
- High precision application
- Horizontal accuracy better than 10 cm
- Challenge: maintain FIX while rotating with boom up
- GPS+GLO provides best results



	% FIX
GPS-only	73 %
GLO-only	68 %
GPS+GLO	99 %

■ - GPS+GLO  
■ - GPS Only



AGI-3 Receiver  
GX-45 Console





# *Area of High Precision GNSS Application – Land Levelling*



**Example of Land Levelling Operation**

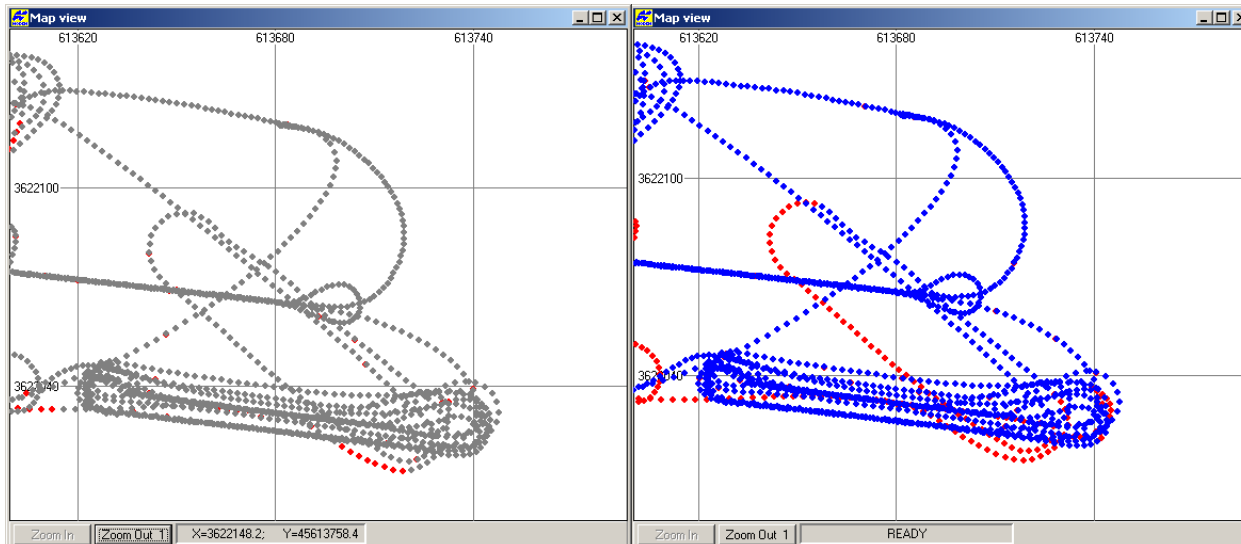


**Vertical accuracy shall be better 3 cm**

# Multi GNSS. Land Levelling



- Land levelling
- High precision application
- Vertical accuracy better than 3 cm
- RTK (GPS + GLO)
- Operation near trees – challenging area
- GPS+GLO provides best results
- When close to trees, only GPS+GLONASS provide reliable high accuracy positioning required for land levelling



	% FIX
GPS-only	92 %
GLO-only	87 %
GPS+GLO	98 %

<span style="color: red;">■</span>	GPS+GLONASS
<span style="color: grey;">■</span>	GPS Only
<span style="color: blue;">■</span>	GLONASS Only



All GNSS receivers as minimum support GPS and GLONASS systems



Two systems (GPS and GLONASS), two frequencies, GNSS boards with digital processing in ASIC



GNSS boards with system-on-chip in ASIC



Multi-system (GPS/GLONASS/GALILEO/COMPASS/QZSS), multi-frequency GNSS boards with system-in-package in ASIC

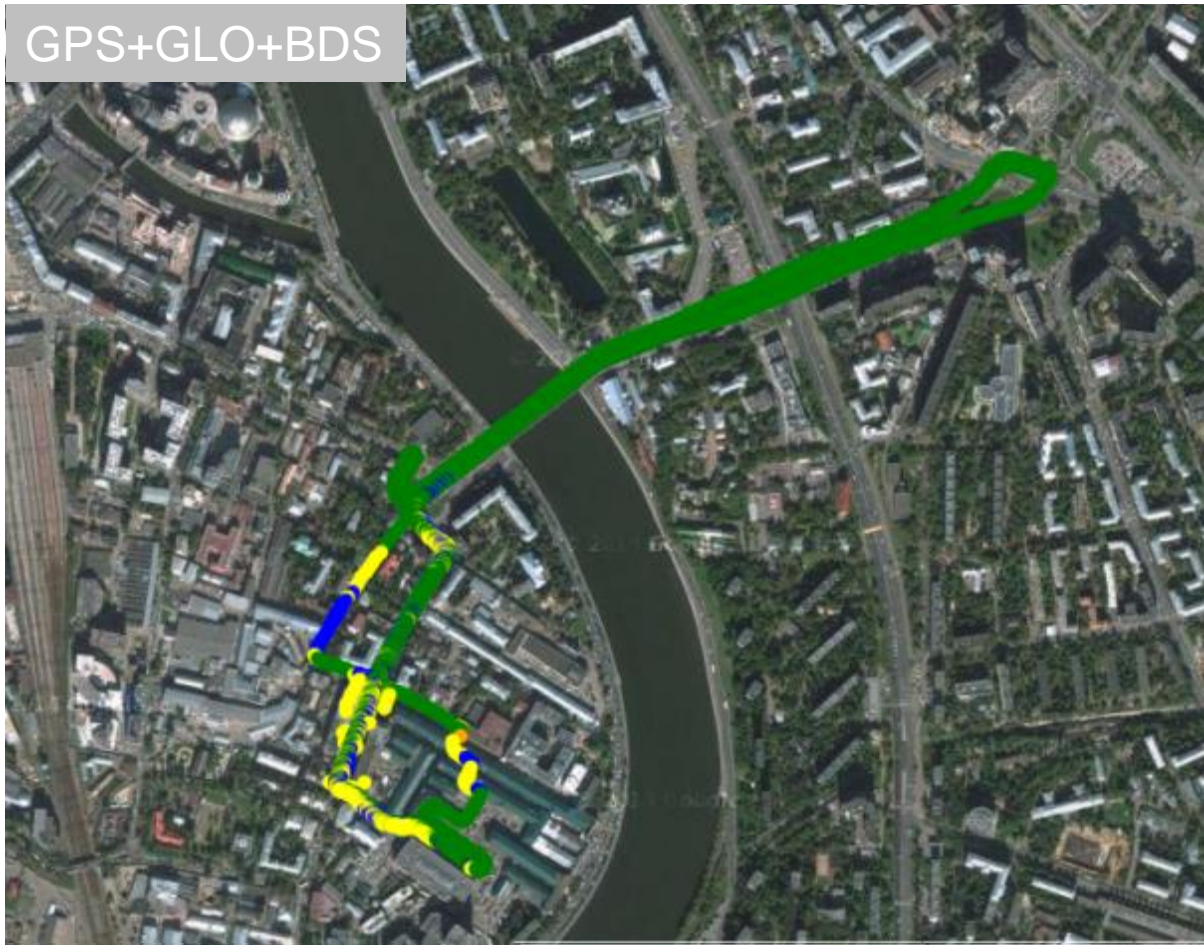
# Multi GNSS in obstructed areas

- Shaded environment (Urban canyons, Moscow)
- RTK (GPS, GLO, BDS)
- As many GNSS available as higher FIX positions availability in shaded environment

% FIX

GPS-only	53.3 %
GLO-only	39.6 %
GPS+GLO	92.4 %
GPS+GLO+BDS	93.2 %

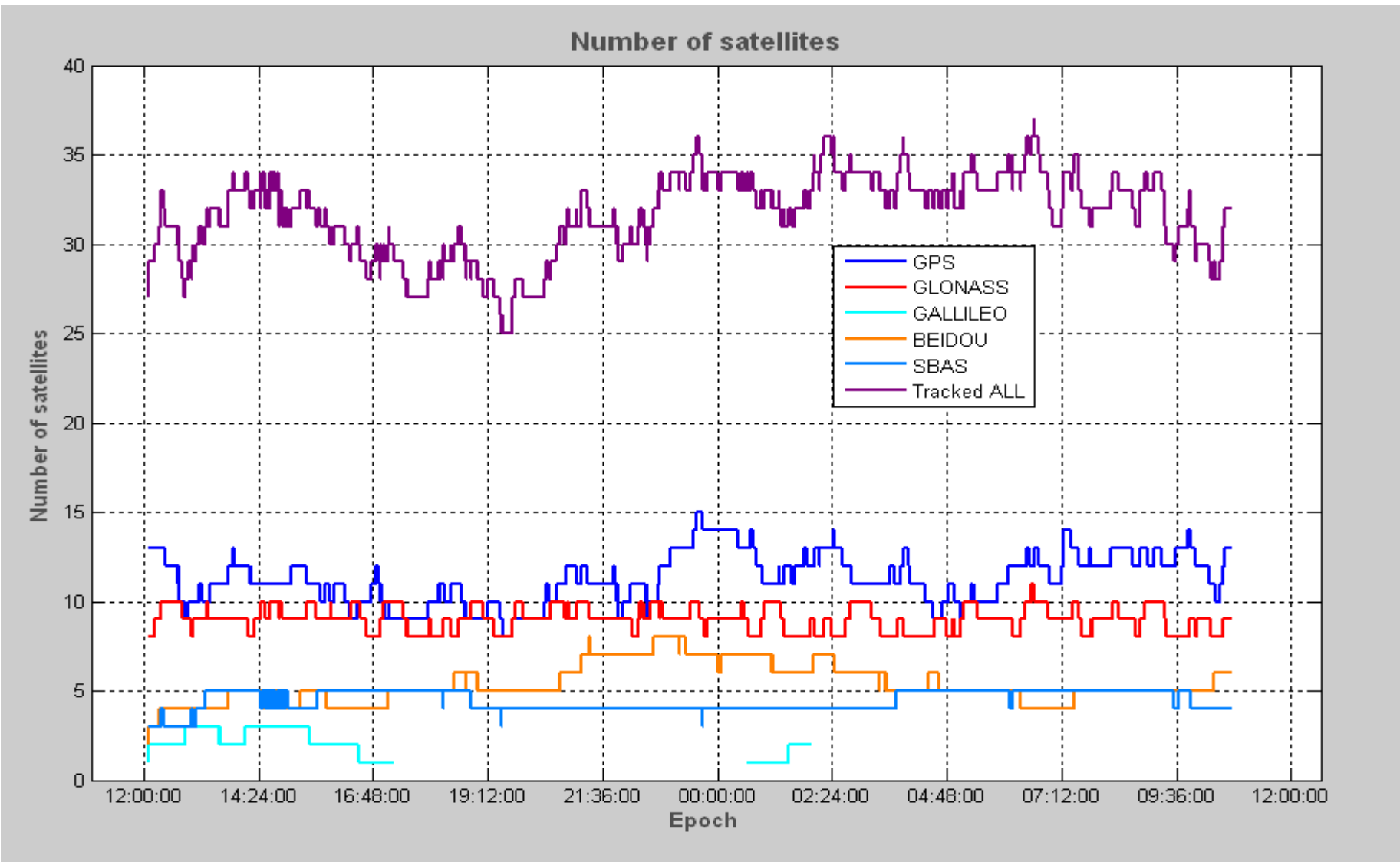
GPS+GLO+BDS



- - NO\_SOLUTION
- - Standalone
- - Code\_DIFF
- - RTK Float
- - RTK Fix

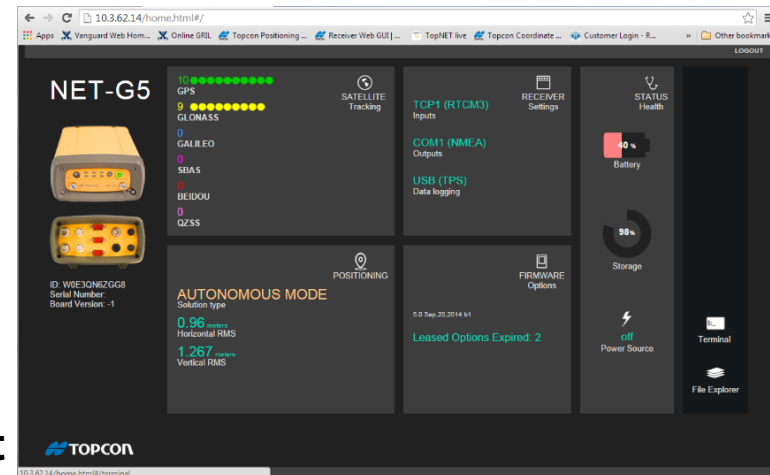


# Example of Satellites for GPS/GLONASS/GALILEO/COMPASS/SBAS





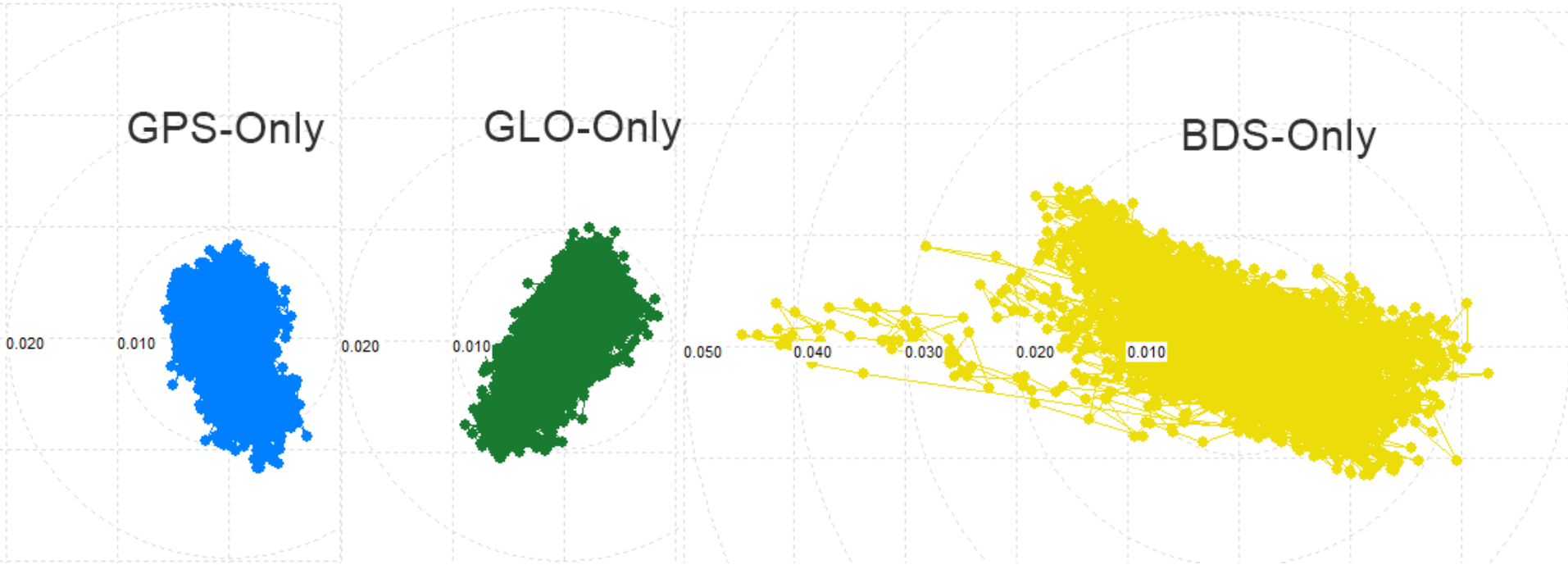
- 452-Channel Vanguard Technology with Universal Tracking Channels
- Tracking multi-frequency signals from all GNSS constellations including GPS, GLONASS, QZSS, Galileo and BeiDou
- Successful tracking and demodulation of advanced QZSS signal structures such as the LEX signal in E6
- High precision code and carrier phase measurements up to 100 Hz
- Built-in Bluetooth® and WiFi® connectivity
- Integrated web interface with advanced receiver management features
- 32GB SDHC storage support
- Extended operation (>15 hours) using integrated batteries
- Support for charging and Power over Ethernet





## *What does multi-GNSS capable receiver really mean?*

- All satellites are equal to each other (GPS, GLONASS, GALILEO, BEIDOU)
- Data processing w/o any constellation preference
- RTK solution with a limited number of mixed satellites
- RTK / PPP solution where only one system is used: GPS or GLONASS or GALILEO or BEIDOU



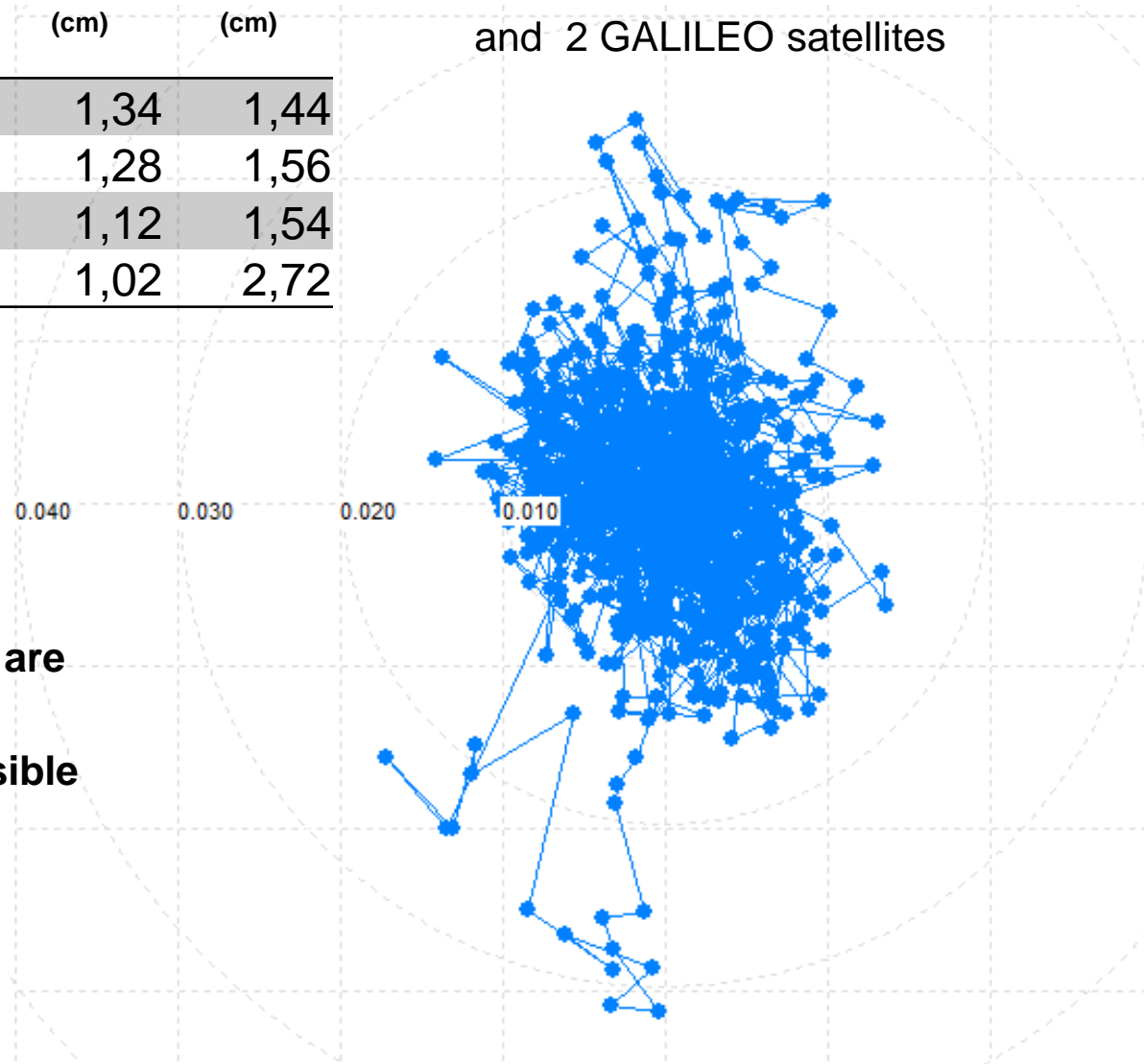
- RTK positioning
- ASIA region
- Static, short base line
- FIXED Solutions

	Accuracy (RMS), mm	98%
GPS-only	3.8	8.6
GLO-only	4.0	8.7
BDS-Only	7.3	17.0



## Trial	GPS Used	GAL Used	Successful Fixed Solutions (%)	Time to fix (sec)	RMS Horizontal (cm)	RMS Vertical (cm)
1	0	4	99,3	2,6	1,34	1,44
2	2	4	99,3	2,2	1,28	1,56
3	3	3	99,3	2	1,12	1,54
4	4	2	99,3	2	1,02	2,72

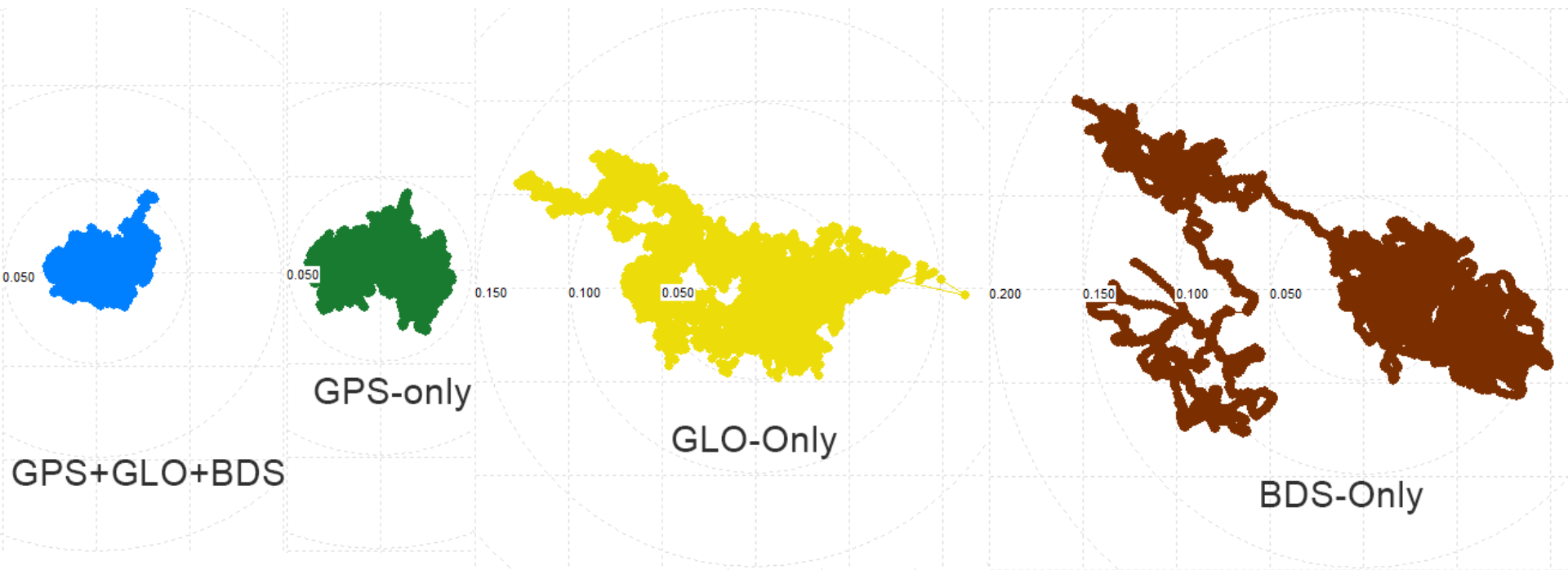
RTK solution with 4 GPS satellites and 2 GALILEO satellites



- RTK positioning
- Europe region (Sweden)
- Short trials
- Just few GPS and GALILEO are used
- GALILEO only solution possible



- Topcon TopNet Global-D PPP service
- Worldwide coverage
- <http://www.topnetlive.com/>



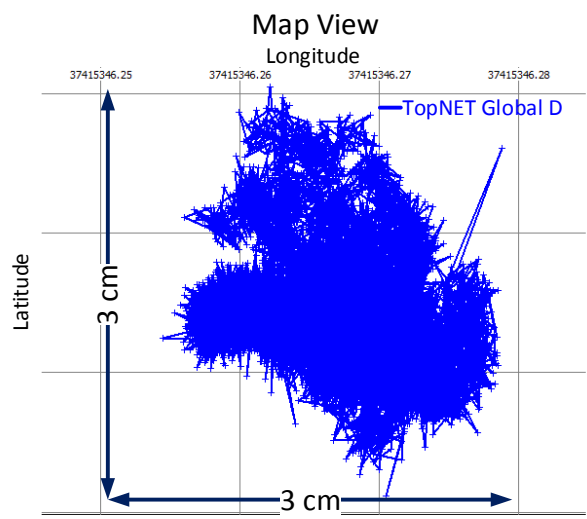
- **PPP positioning**
- **Asia / Europe region**

	Accuracy (RMS), cm	98%, cm
GPS+GLO+BDS	1.3	2.9
GPS-only	2.2	3.8
GLO-only	3.2	6.1
BDS-only	7.2	15.8

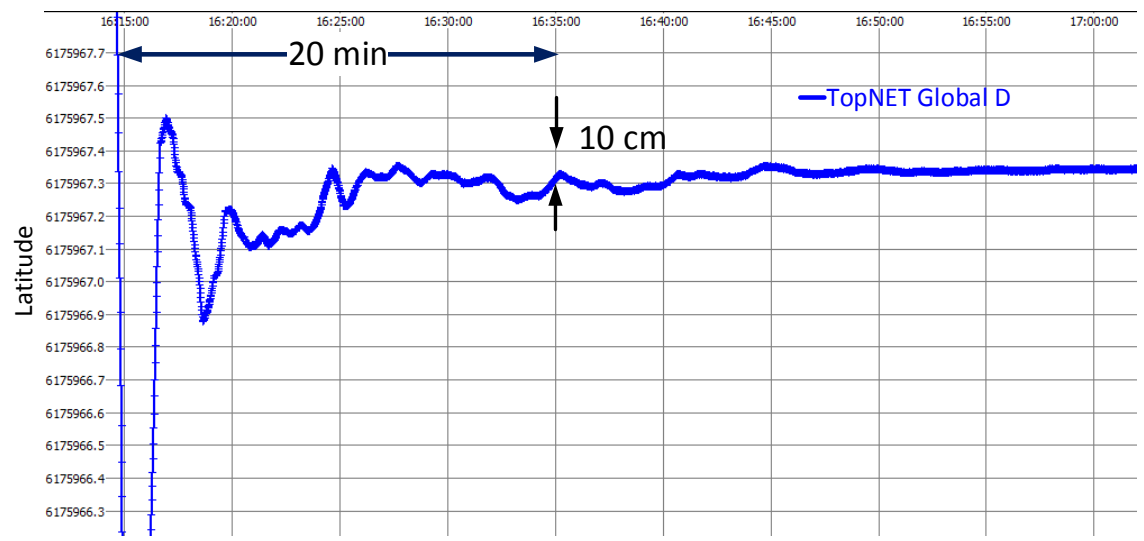


## Accuracy and first convergence period for the clear sky conditions and GPS and GLONASS GNSS. Static.

### Accuracy after convergence



### Convergence period



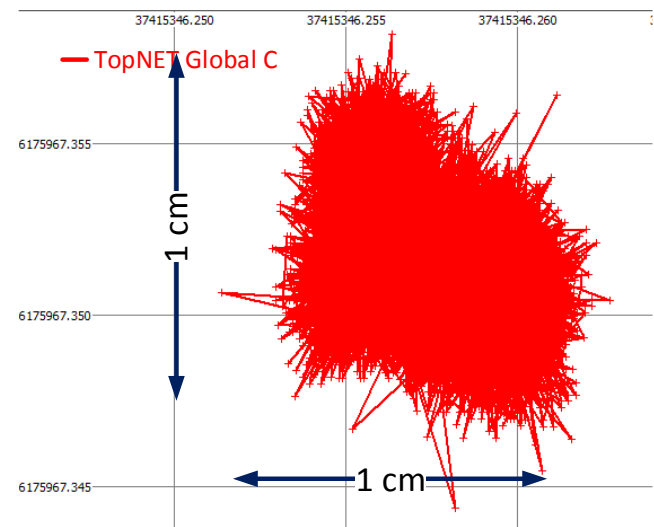
### Precision statistic (STD) after convergence for TopNET Global D. Static.

Mode	Value	Standard Deviation (m)				
		Latitude	Longitude	Height	2D	3D
TopNET Global D		0.002	0.004	0.004	0.005	0.006

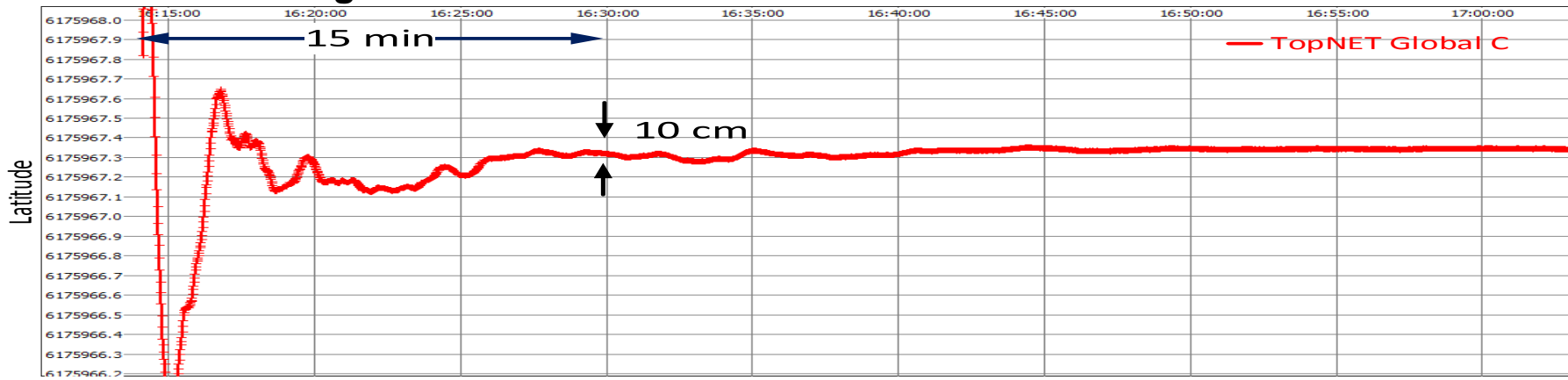
Service provides:

- a few centimeter accuracy (5-6 cm);
- convergence time less than 30 minutes;
- supporting GPS and GLONASS GNSS;
- more stable solution than Float PPP solution;
- improvements in first convergence period and Fast Reconvergence features.

## Accuracy after convergence



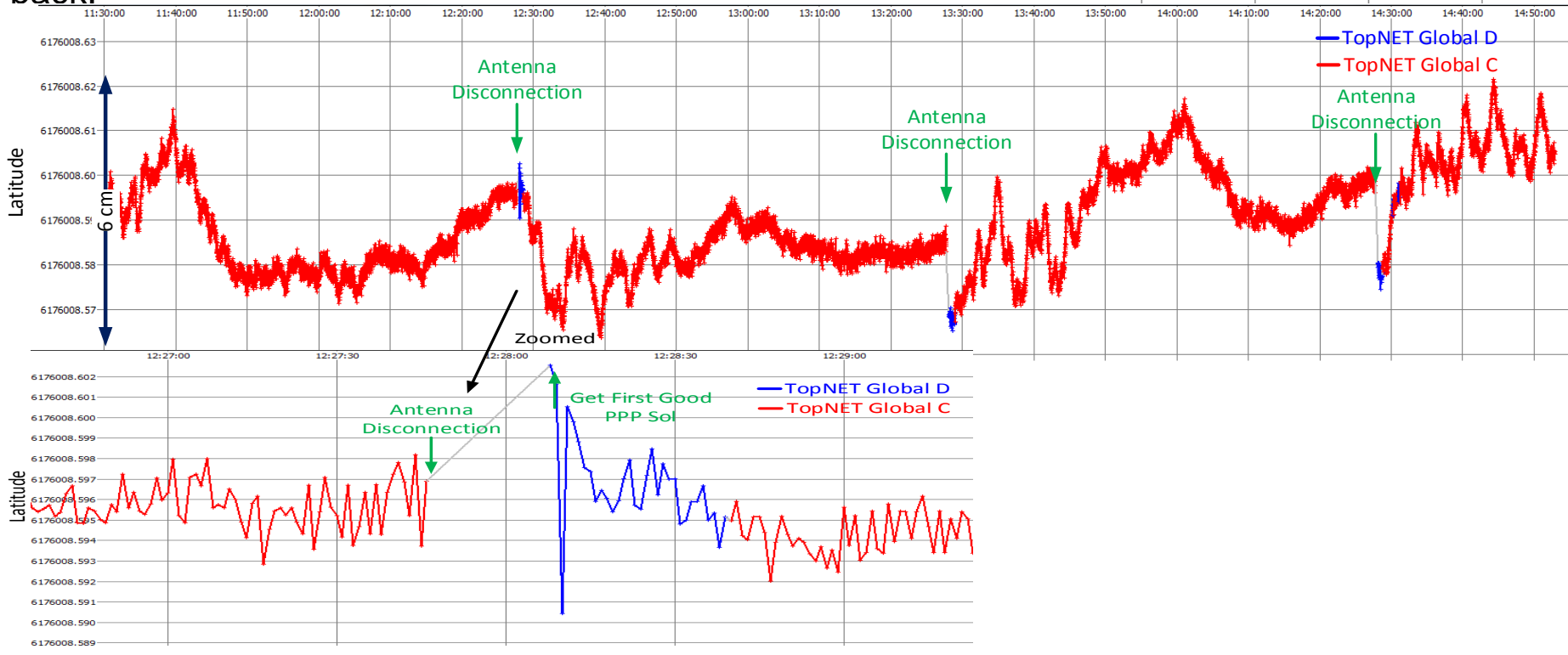
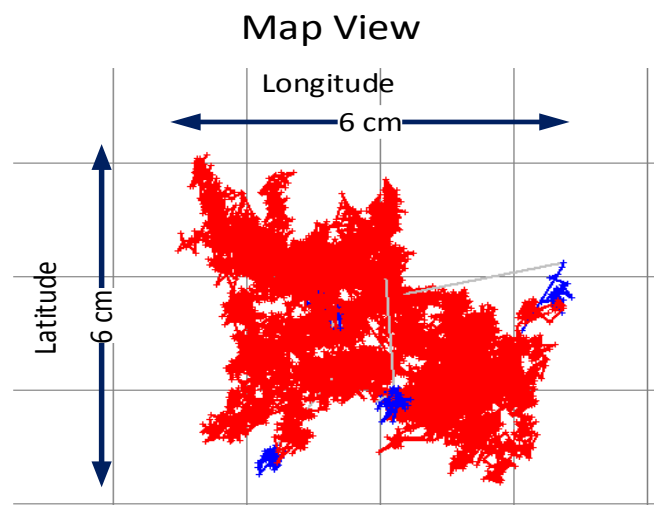
## Convergence Time to 10 cm



Mode	Value	Standard Deviation (m)				
		Latitude	Longitude	Height	2D	3D
TopNET Global C		0.002	0.002	0.003	0.002	0.003

**Fast Reconvergence** feature provides user with a possibility to get fast high accuracy using PPP algorithms after shading or obstacles.

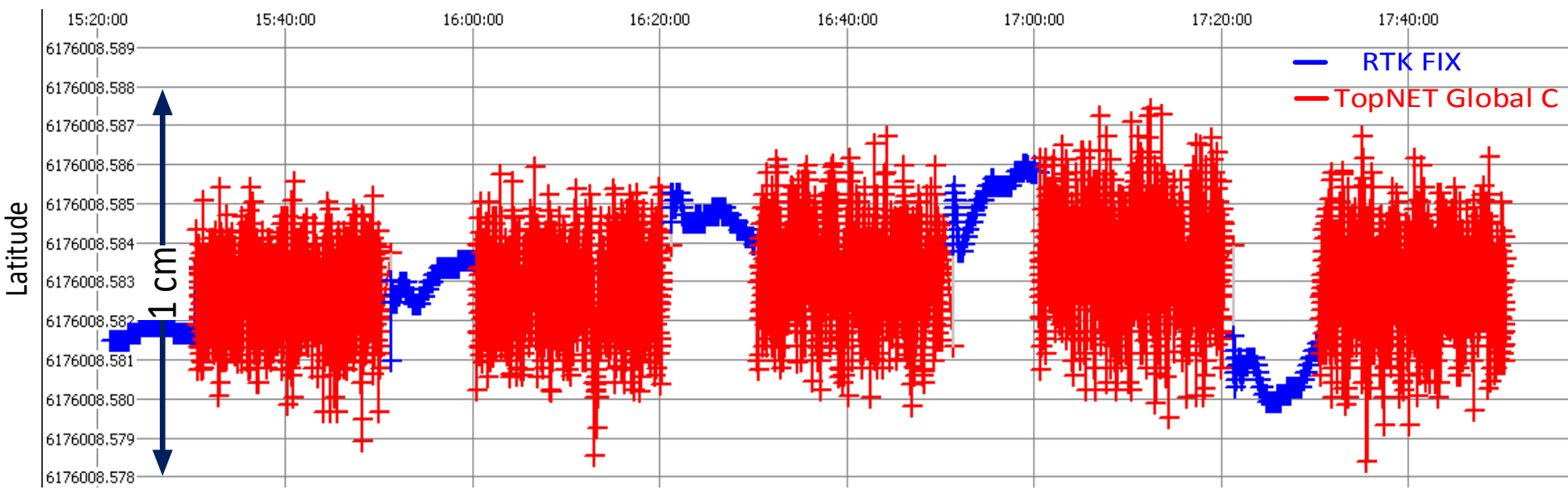
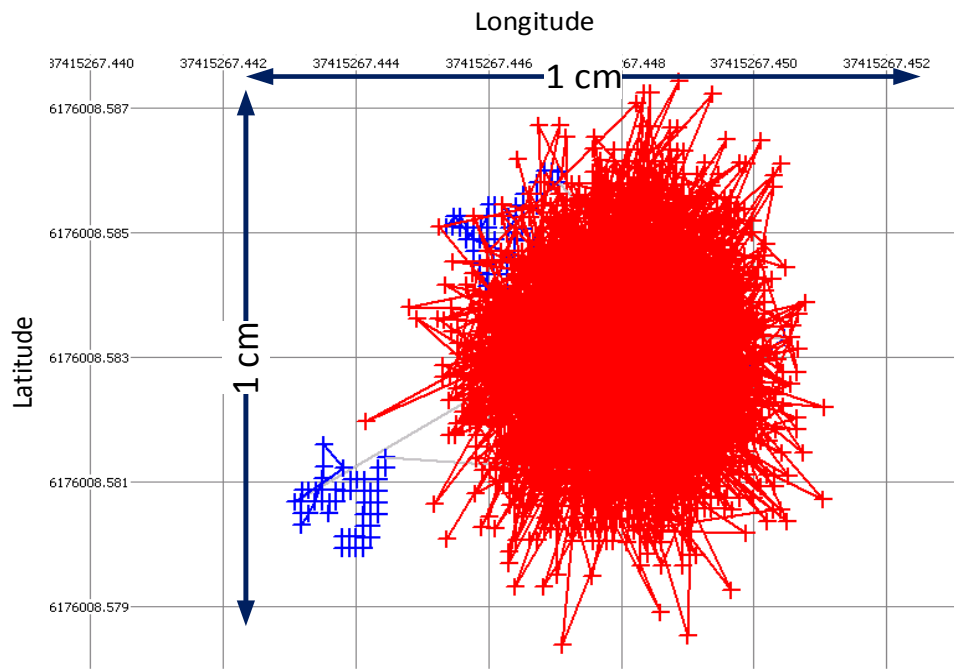
**Test scenario** - Every 30 minutes GNSS antenna has been disconnected from navigation receiver for 20 seconds. After that only few seconds are needed to get converged solution back.



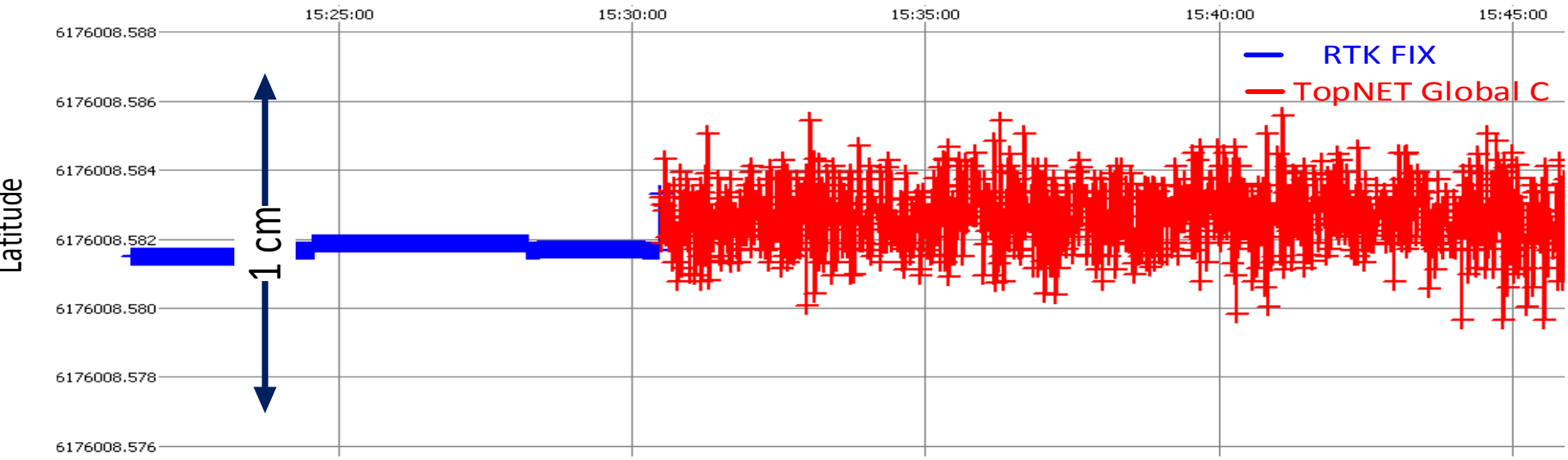


- **SkyBridge feature** allows RTK user to get high accuracy navigation solution in the case of absence RTK corrections or RTK fix solution;
- SkyBridge provides TopNET Global-C solution without **first convergence** and with **improved accuracy** using RTK FIX position for seeding;
- SkyBridge uses mix of **RTK** and **PPP** technologies;
- RTK is a **differential positioning technology** and it provides **high accuracy** navigation solution **relative to base station** coordinates;
- PPP is an **absolute navigation technology** that provides sub decimeter accuracy in the ECEF **absolute coordinate system** (ITRF 2014).

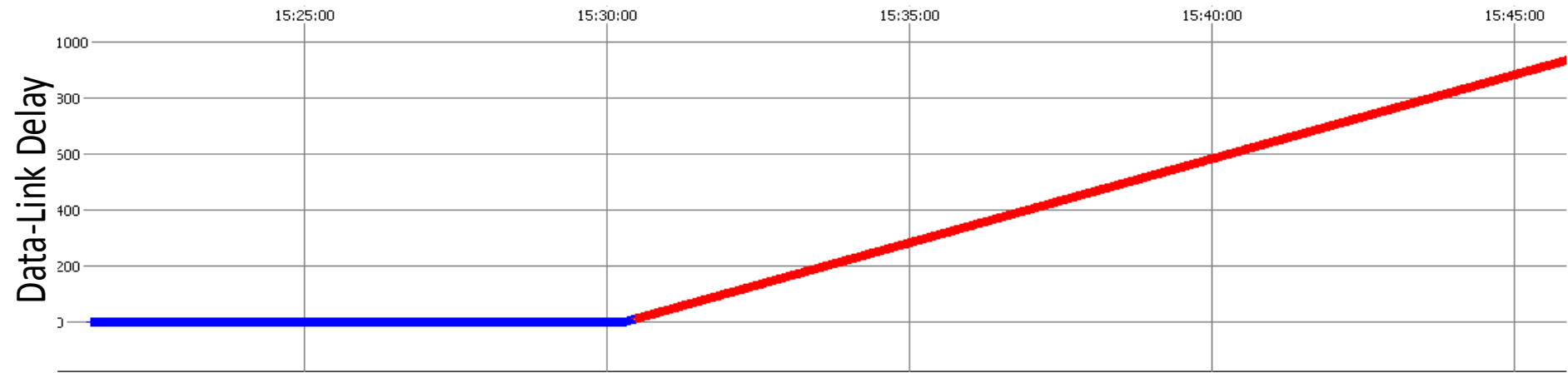
- **Test setup:**
- **After 10 minutes of operation RTK corrections have been terminated for 20 minutes.**
- **Several iterations have been made.**
- **RTK Base has precise coordinates in ITRF 2014.**



Zoomed instantaneous seeding from RTK Fix to TopNET Global-C solution when Data-Link has been lost

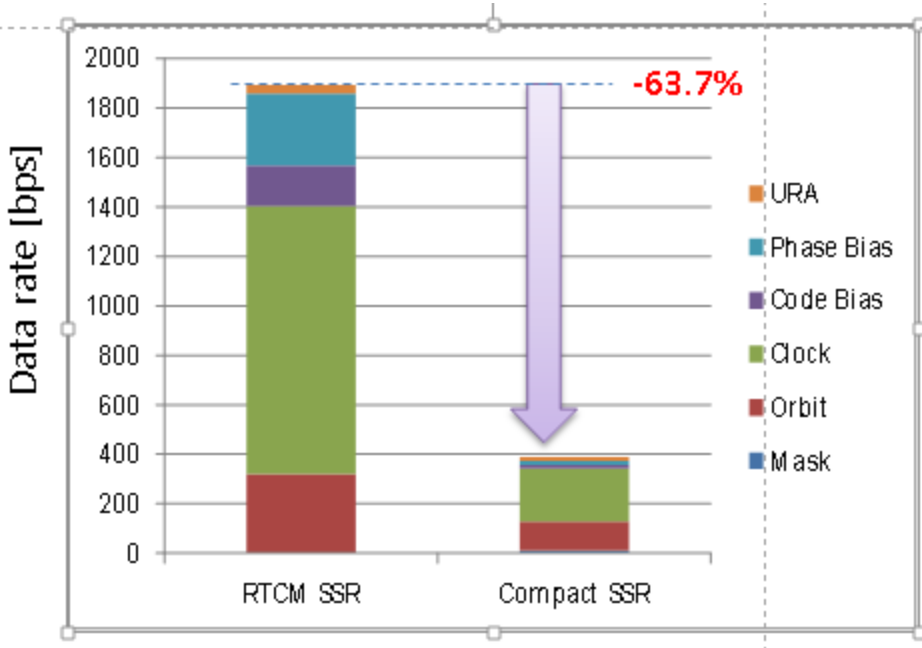
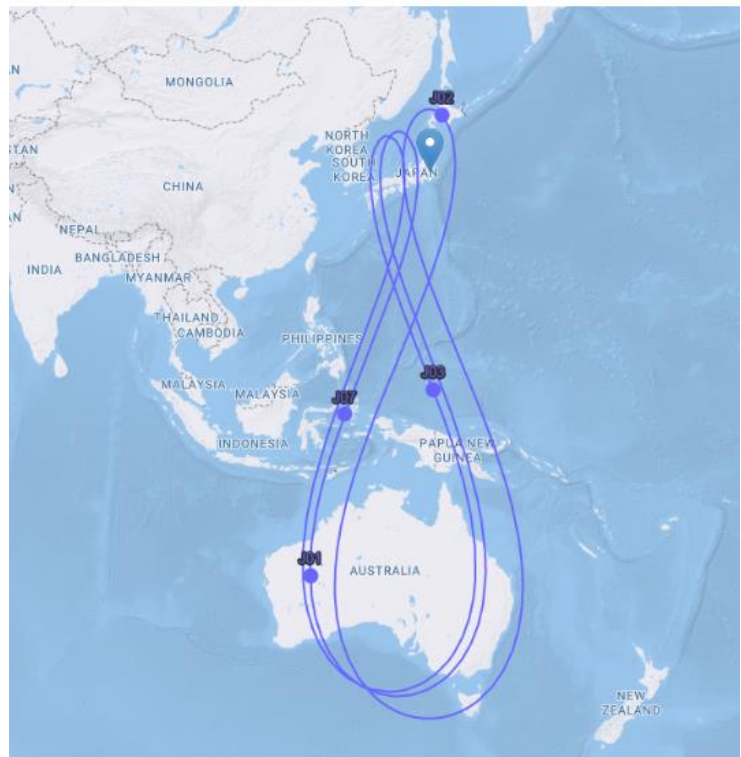


## Base corrections Delay





- QZSS covers East Asia and Oceania region;
- CLAS – free open PPP service;
- Service provides precise corrections in RTCM3 Compact SSR format – CSSR;
- CSSR transmits precise orbits, clocks, code and phase biases, troposphere and ionosphere corrections.
- CSSR format much more effective than SSR

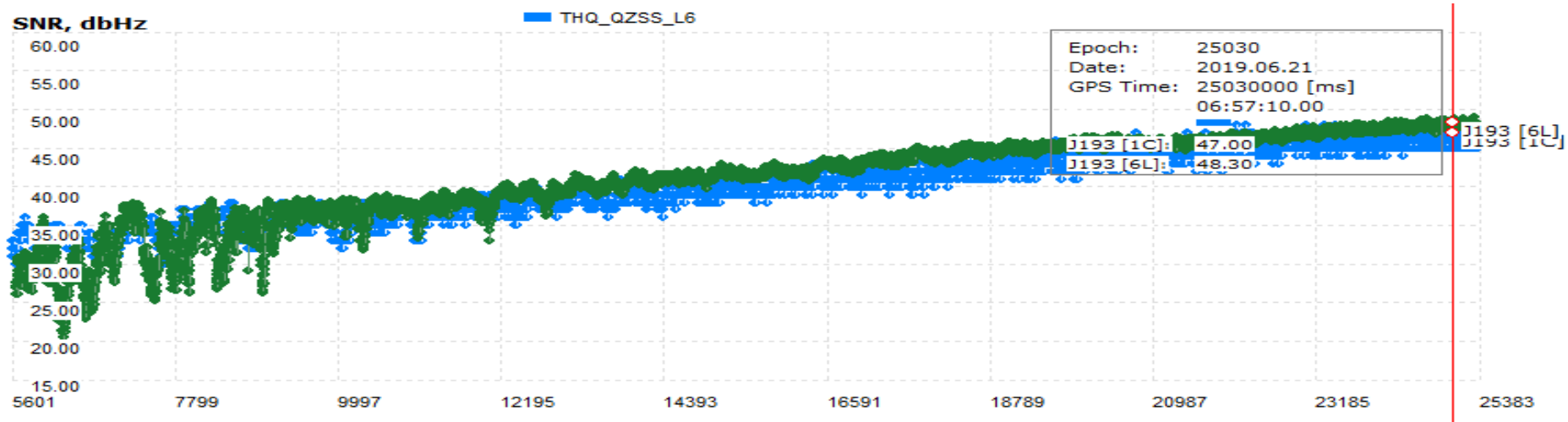


Type	Interval
Clock	5sec
Orbit, Code Bias, Phase Bias, URA, Mask	30sec
Troposphere, Ionosphere	30sec

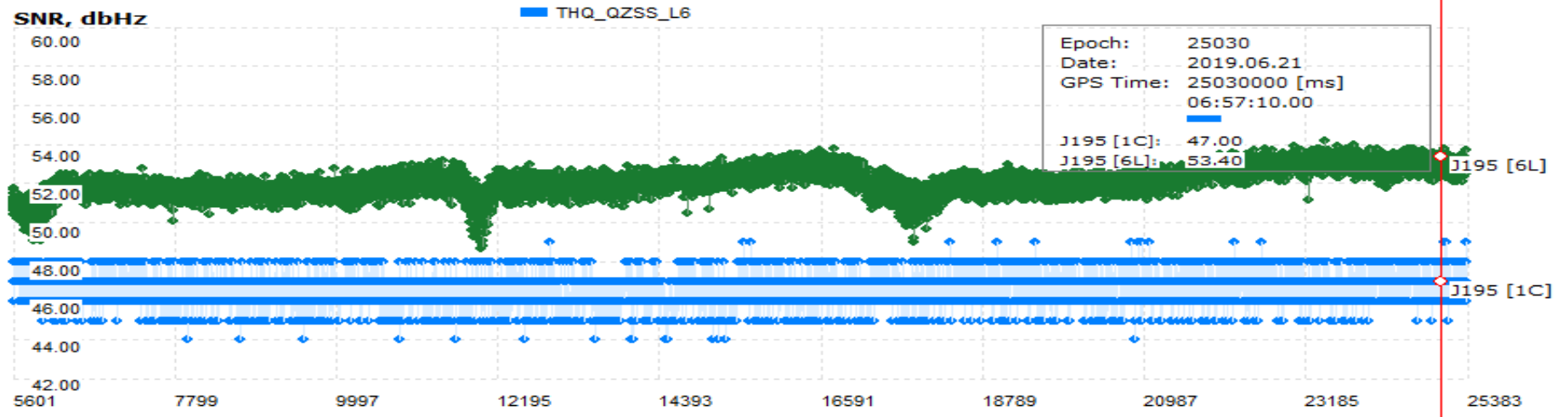
- Net-G5 base and Hiper HR rover support the QZSS CLAS;
- Tracking the QZSS satellites;
- Output of RAW bitstream;
- Output of PPP solutions.

Feature	First FW	Future Firmware
SVs support	QZS-1	QZS-1,QZS-2,QZS-3,QZS-4
PRNs support	193	any two (192,194,195,196,197)
Raw measurement	QZS-1 L6-pilot	QZS-1 L6-pilot
CLAS raw stream	QZS-1	QZS-1,QZS-2,QZS-3,QZS-4
RCTM3	no	Yes
PPP solution	no	Yes

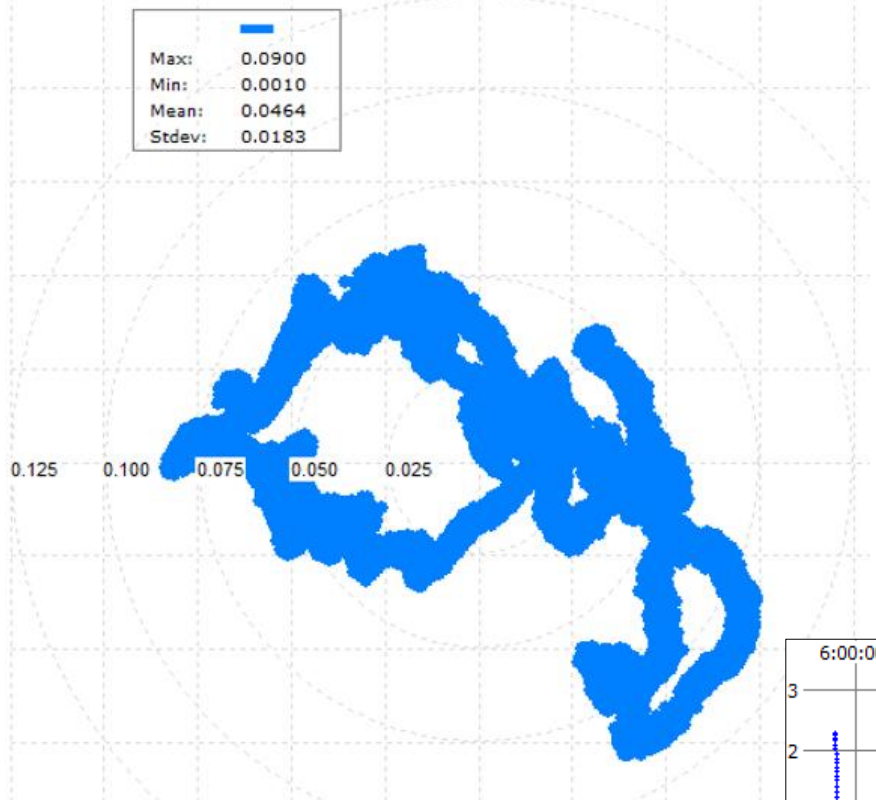
## QZSS PRN 193



## QZSS PRN 195



Horizontal View, m



- **PPP positioning**
- **CLAS service**
- **Precise corrections to GPS, GALILEO and QZSS**
- **Japan region**

**PPP horizontal accuracy after convergence, cm**

	RMS	95%
	4.99	7.86

