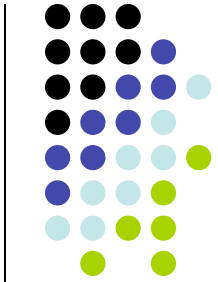


Precise Point Positioning (PPP) Based on State Space Representation (SSR) Utilizing Quasi-Zenith Satellite System

Taro Suzuki
Tokyo University Marine Science and Technology

QZSS

- QZSS (Quasi-Zenith Satellite System)
  Regional navigation service is broadcasted from high-elevation angle on the inclined geosynchronous (quasi-zenith) orbit;
  - The first QZS satellite was successfully launched on Sept. 11, 2010.
  - Broadcast GPS-compatible signals on three frequencies and two augmentation signals, L1-SAIF and LEX;


Driving control of tractor


Blade control of bulldozer


Mobile Mapping System

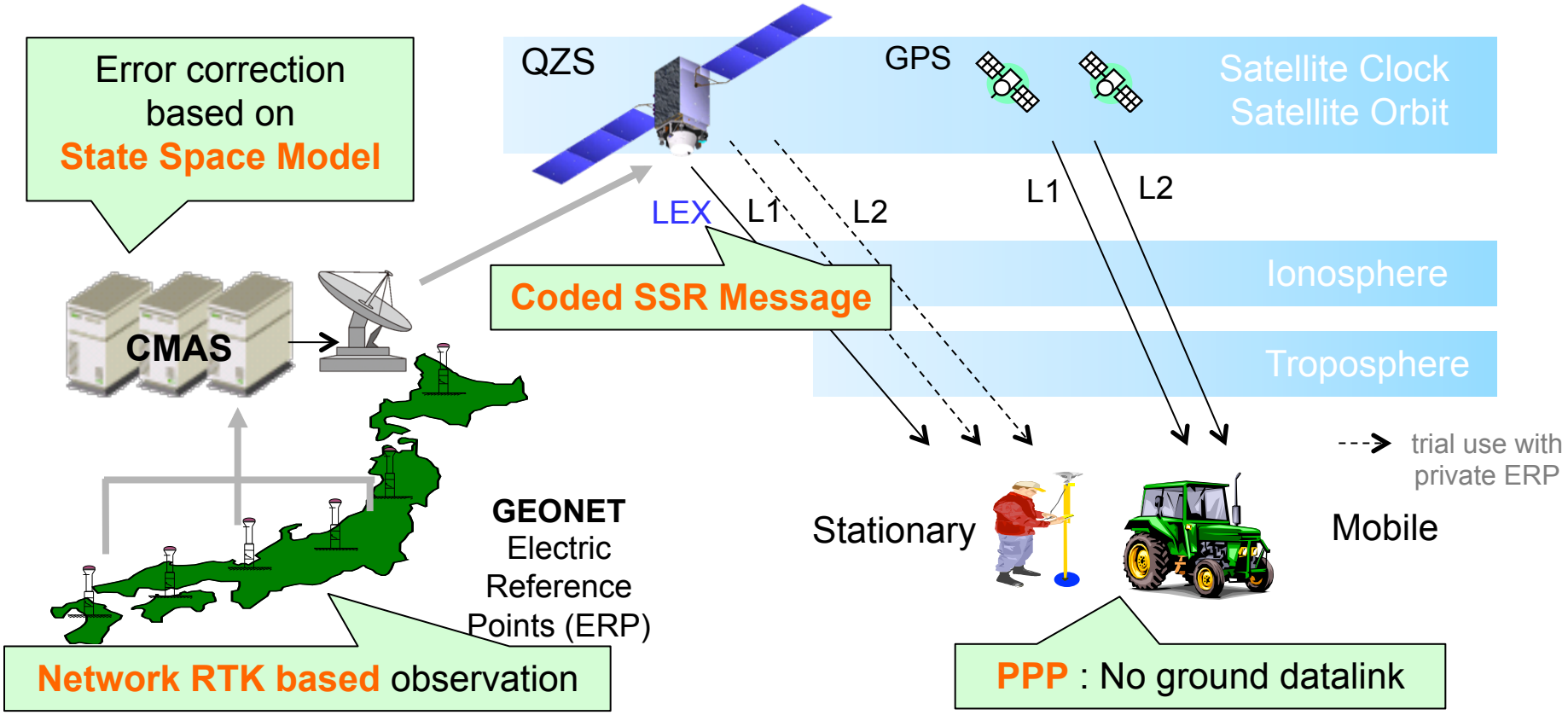

Detection of Tsunami


Land Survey

Demand for high precision positioning!

Centimeter-class Augmentation System

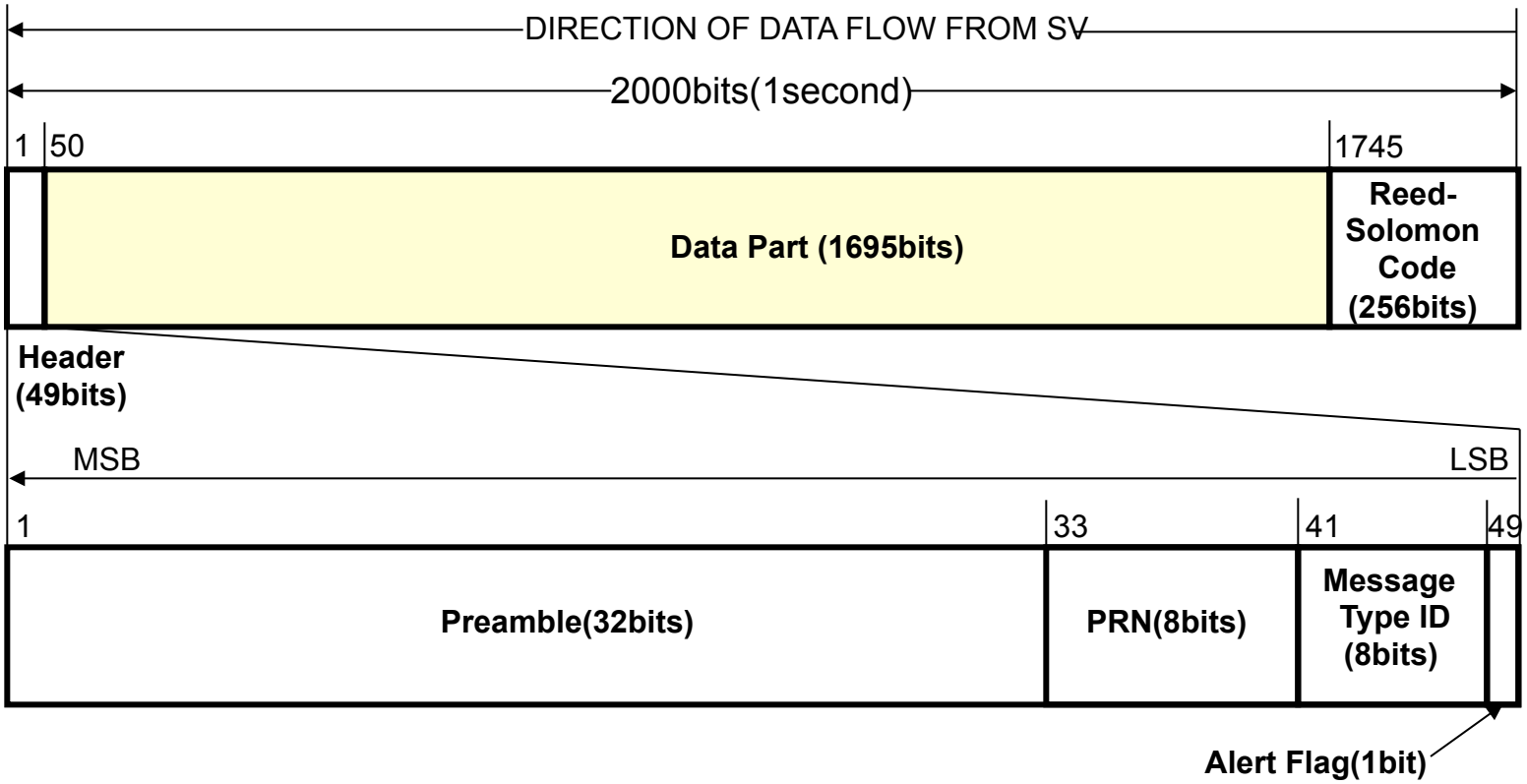
CMAS is the centimeter-class augmentation system utilizing QZSS
- adopt "SSR method" computing based on State Space Model (SSM)
- generate corrections in form of State Space Representation (SSR)
- distribute Coded SSR Message via QZSS LEX signal



LEX Message Structure

The LEX message frame consists of a 49 bit header, **1695 bits of data** and 256 bits for error correction using Reed Solomon Coding. The total size of one message is 2000 bits. The actual transfer volume for augmentation data is 1695bps

LEX: L-band Experimental signal (1278.75MHz)



CMAS SSR Message

State Space Representation (SSR) method is utilized for estimation of error components and generation of augmentation.

1. SSR method provides each error component separately.

2. We are able to choose transmitting period and spatial grid span of each component based on its physical characteristics.

3. the total message amount is dramatically reduced and the required accuracy is still achieved concurrently.

Transmission Item	Components	Update period [s]
High-speed correction items	Satellite Clock Correction	5
Low-speed correction items	Satellite Orbit Correction	30
	Local Ionosphere Correction	30
	Local Troposphere Correction	30
	Signal Bias Correction	30
Integrity information		30
Others (Preamble, GPS week/second, IODE, PRN)		30

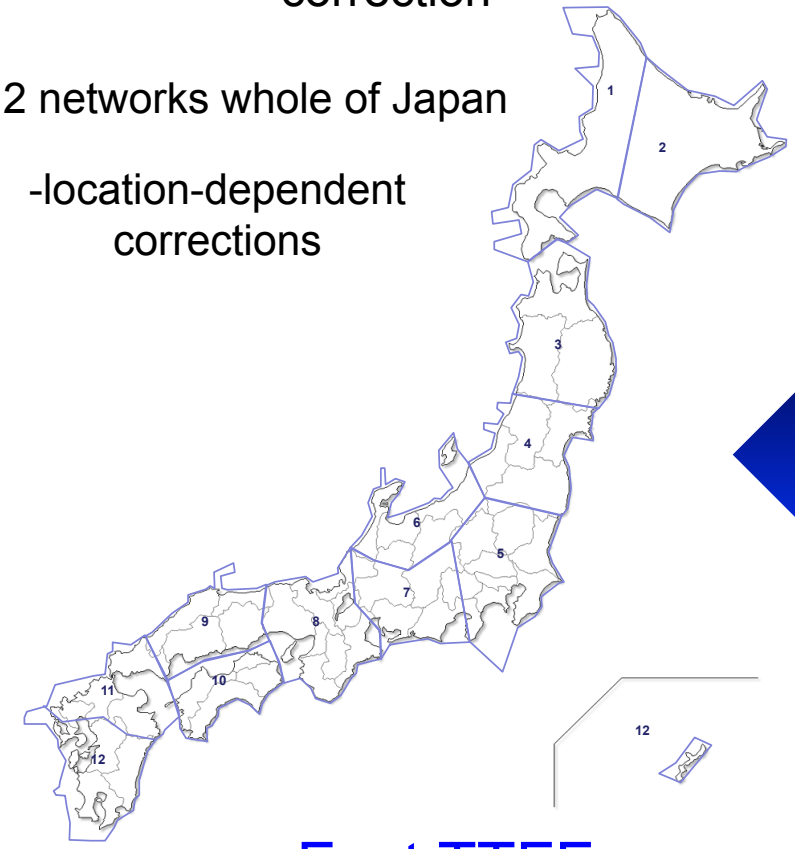
➡ The effect of local Ionosphere and troposphere correction

Local vs. Wide-area System

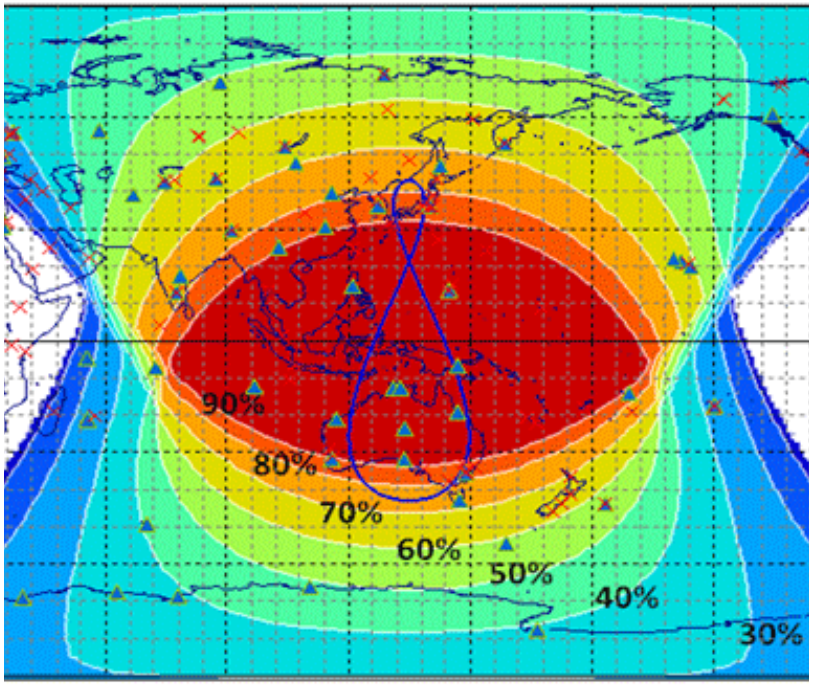
With Local Ionosphere and Troposphere correction

12 networks whole of Japan

-location-dependent corrections



Without Ionosphere and Troposphere correction



Fast TTFF
Local area

Wide area
Slow TTFF

We consider that PPP
using CMAS SSR without local Ionosphere and troposphere correction

Objective

QZSS LEX Signal

Evaluation of Centimeter-class Augmentation System (CMAS) based on SSR for PPP

1. Evaluation the accuracy of ephemeris of broadcasted CMAS SSR message
2. Evaluation the accuracy of PPP using CMAS SSR without ionosphere and troposphere correction

Ionosphere

➡ estimated by the L1 L2 ionosphere free linear combination

Troposphere

➡ estimated by the Kalman filter

Evaluation the accuracy of CMAS SSR

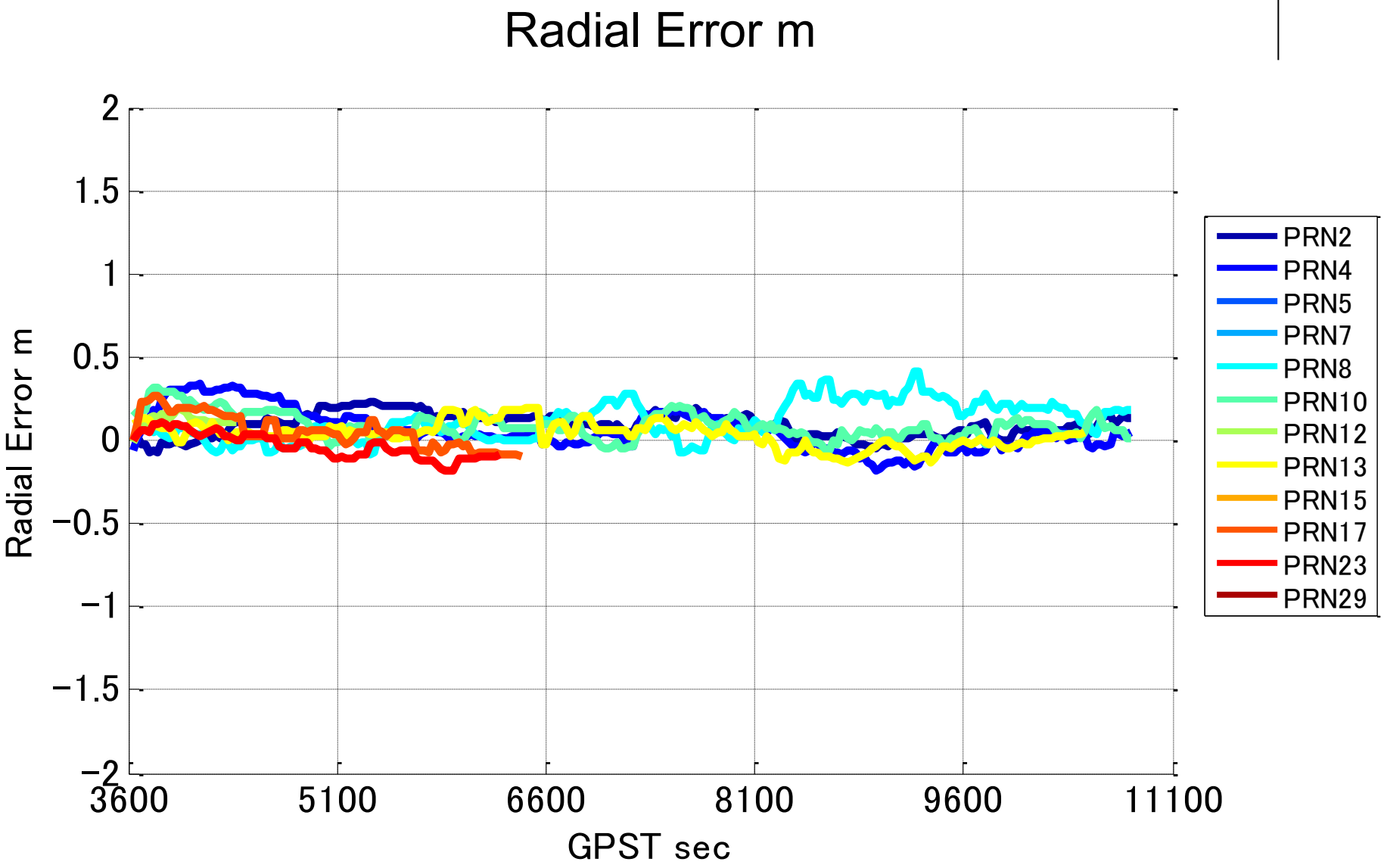
Evaluation the accuracy of ephemeris of broadcasted CMAS SSR message

- Compare with IGS Final SP3

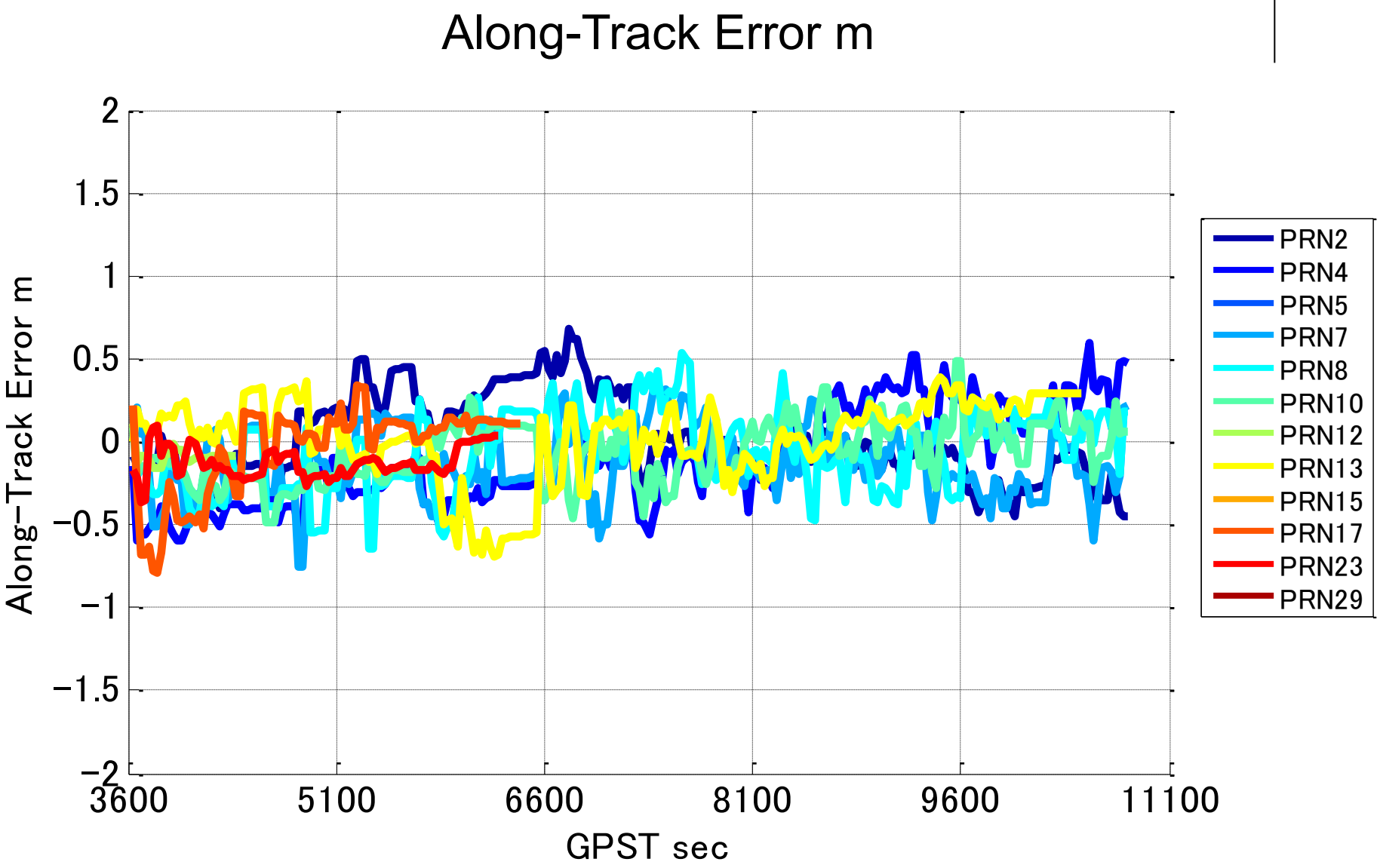
Analysis Condition

- 2012/2/22 1:00～3:00（UTC）
- Using broadcasted CMAS SSR Message
  - RTCM3.1 1057
- Using IGS Final（SP3）
  - Orbit：~2.5 cm, Sat. clock：~75 ps RMS, ~20 ps Sdev
- Using igs08.atx antenna model

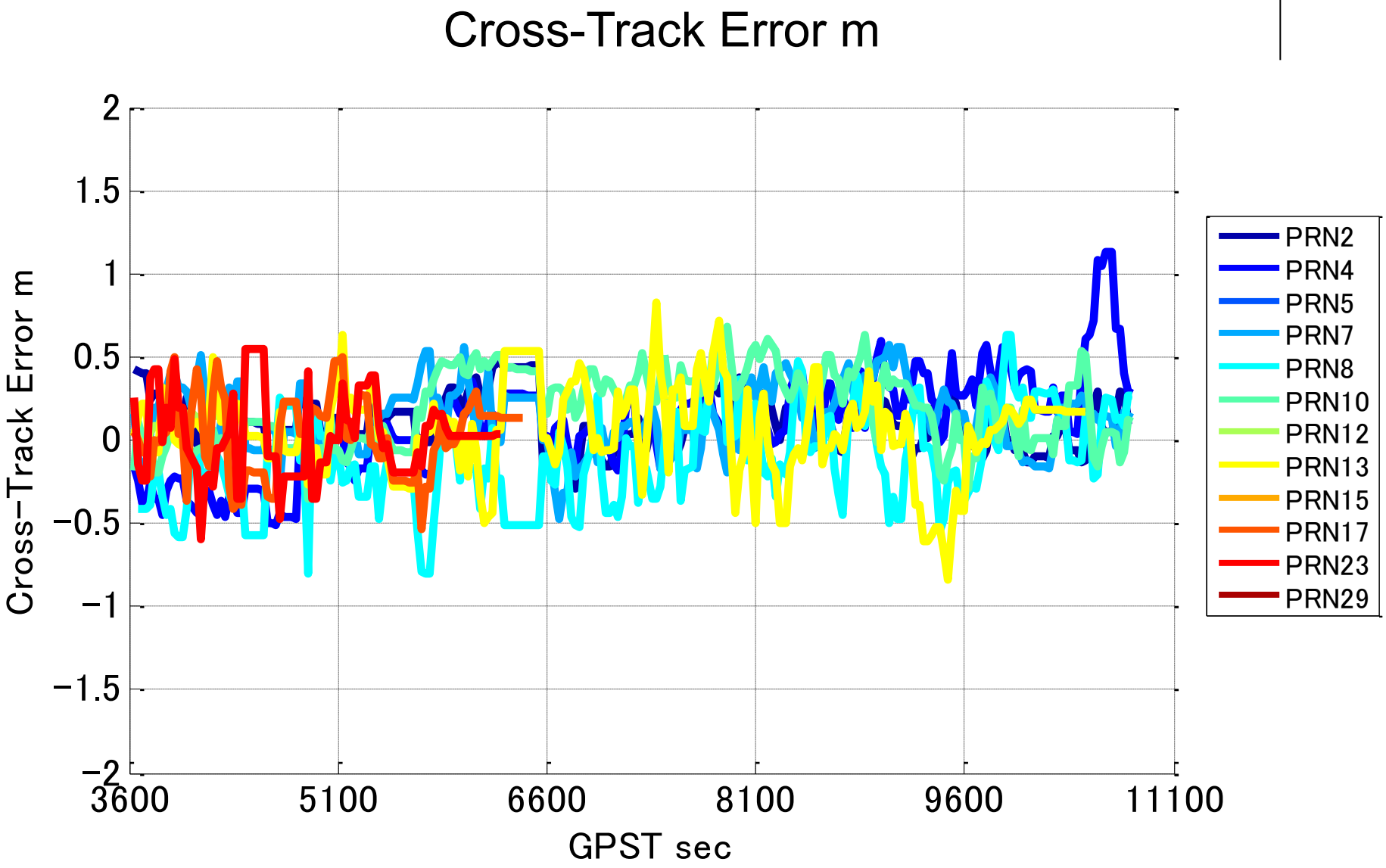
Evaluation the accuracy of CMAS SSR



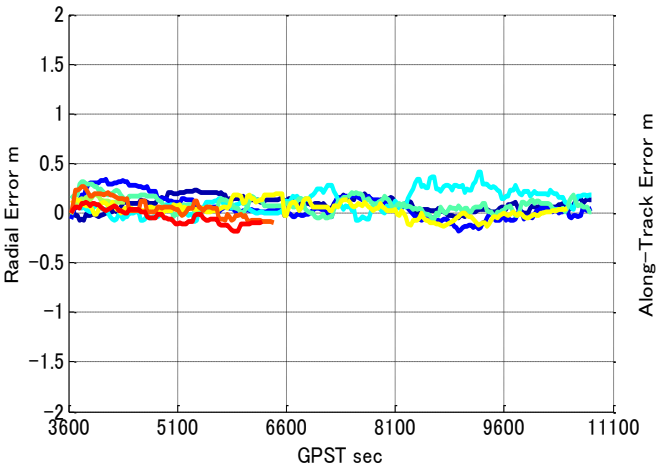
Evaluation the accuracy of CMAS SSR

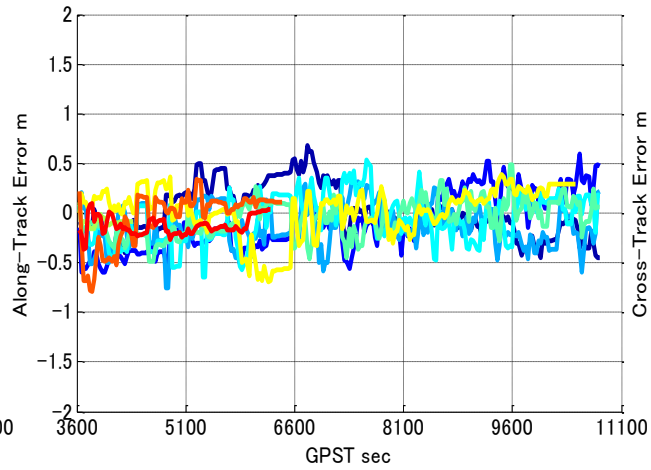


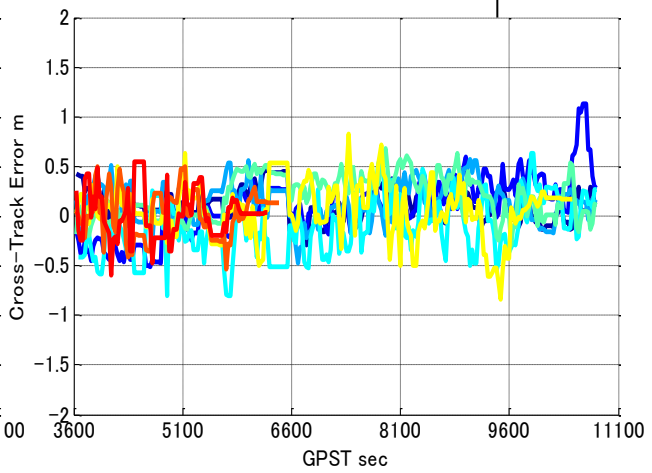
Evaluation the accuracy of CMAS SSR



Evaluation the accuracy of CMAS SSR







	RMS	STD	3D RMS/STD
Radial Error m	0.117	0.084	0.352 0.311
Along Track Error m	0.220	0.202	
Cross Track Error m	0.248	0.221	

CMAS SSR can be applicable to Sub-Decimeter PPP !

Evaluation the accuracy of CMAS PPP

Evaluation the accuracy of PPP using CMAS SSR
without ionosphere and troposphere correction

- Using GEONET observation data (Static)
  - UTUNOMIYA station

Analysis Condition

- 2012/2/22　1:00～6:00（UTC）
- Using GEONET observation data (1Hz)
- Using igs08.atx antenna model
- PPP Engine: RTKLIB
  - Modified for CMAS SSR Message

PPP Model

Ionosphere

- estimated by the L1 L2 ionosphere free linear combination

Troposphere

- estimated by the Kalman filter

PPP mathematical formula

C1PRC = -(-CLK+ORB+TROP+120/154*ION+C1Bias-earthtide)

P2PRC = -(-CLK+ORB+TROP+154/120*ION+P2Bias-earthtide)

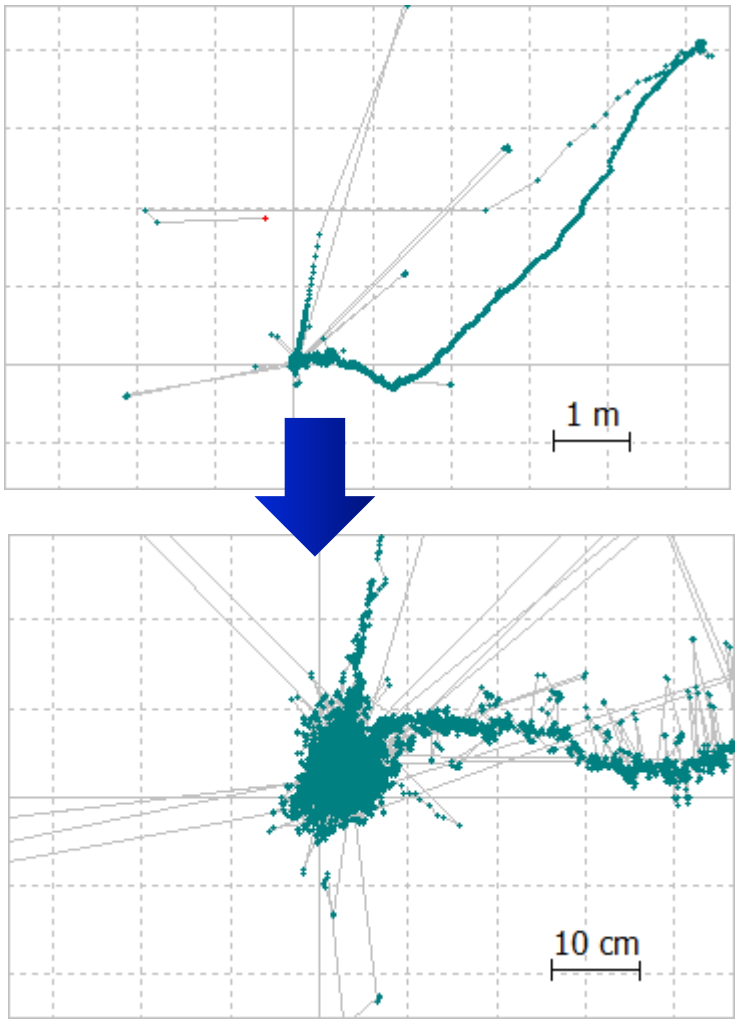
L1PRC = -(-CLK+ORB+TROP-120/154*ION+L1Bias-earthtide-wupL1)

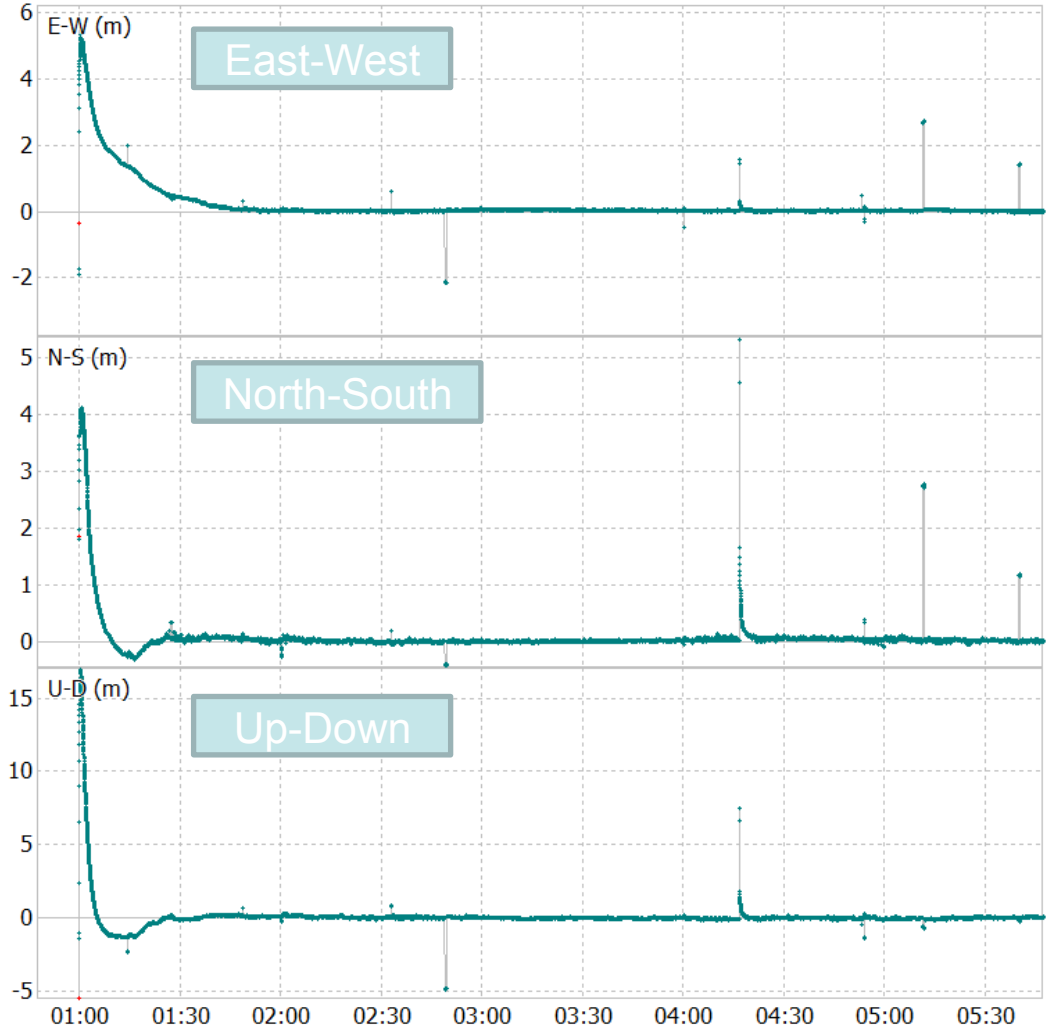
L2PRC = -(-CLK+ORB+TROP-154/120*ION+L2Bias-earthtide-wupL2)

ION: the ionosphere-free linear combination
TROP: estimated delay

PPP Results (1)

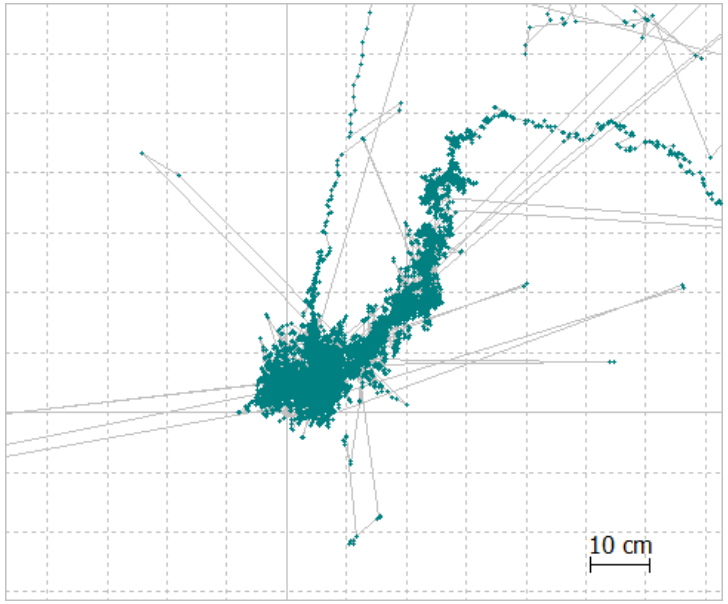
Code/Carrier-Phase
Error Ratio : 800

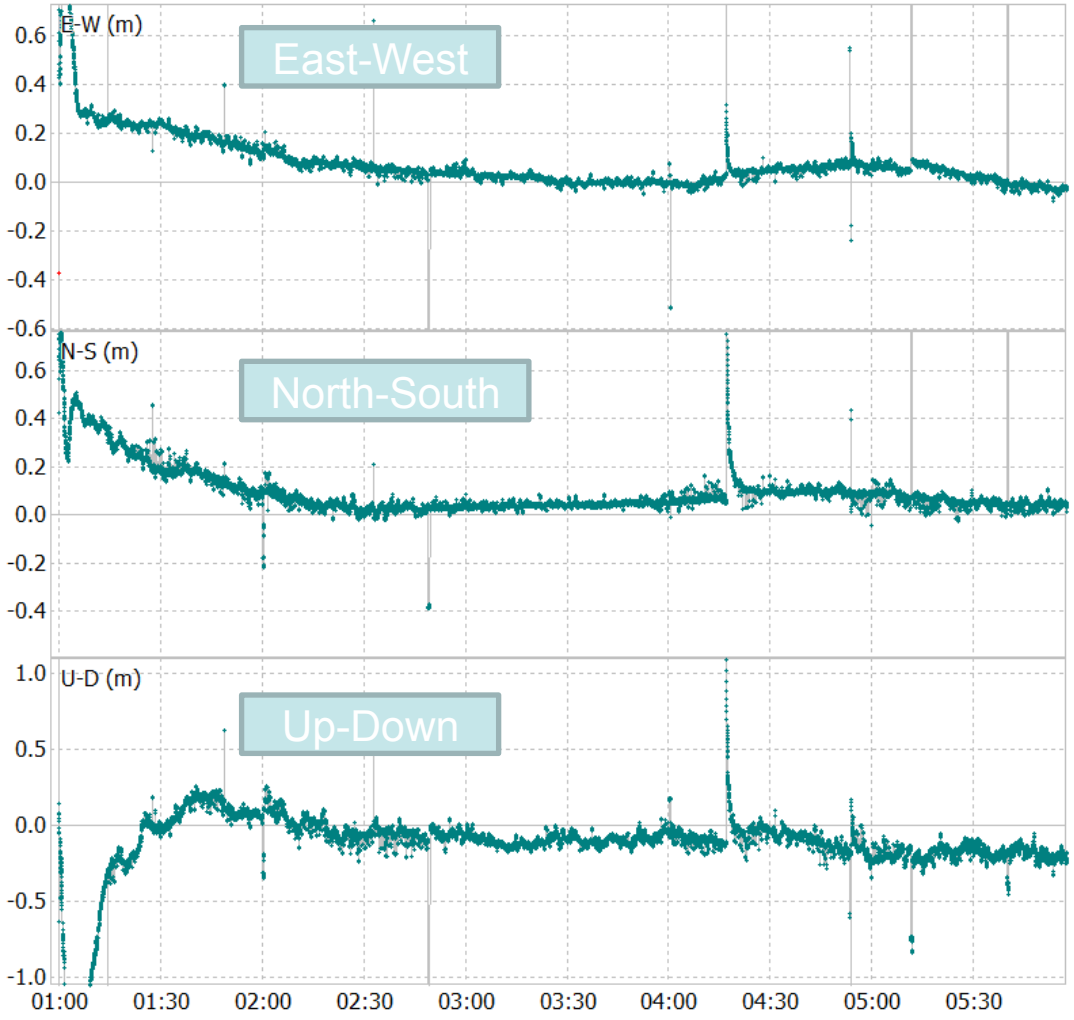




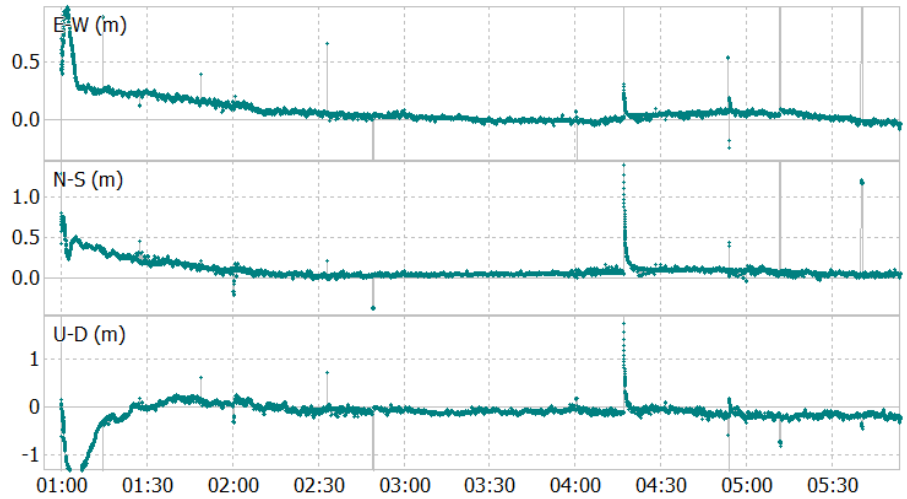
PPP Results (2)

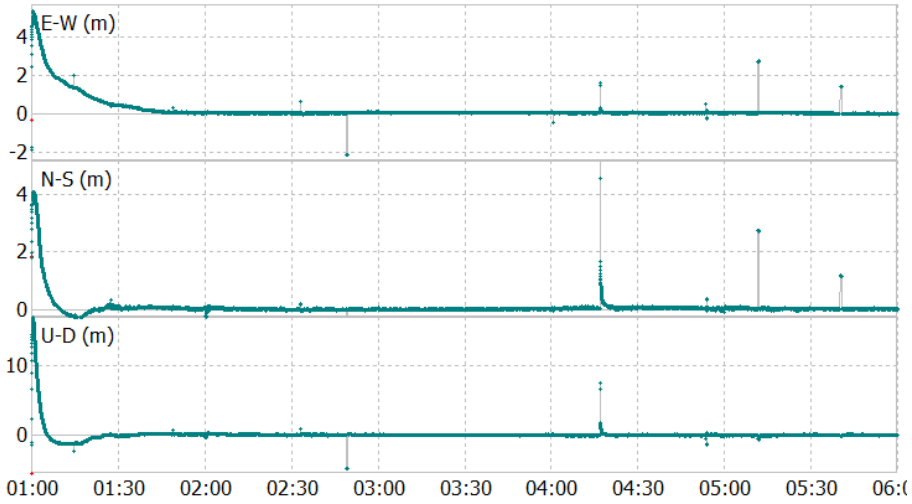
Code/Carrier-Phase
Error Ratio : 100





PPP accuracy and TTFF





Code/Carrier-Phase Error Ratio	100	800
East RMS	0.162	0.160
North RMS	0.187	0.177
UP RMS	0.179	0.125
TTFF (<20cm)	32 min	40 min

CMAS SSR can be applicable to wide area PPP !

Conclusion

QZSS LEX Signal

Evaluation of Centimeter-class Augmentation System (CMAS) based on SSR for PPP

1. Evaluation the accuracy of ephemeris of broadcasted CMAS SSR message
2. Evaluation the accuracy of PPP using CMAS SSR without ionosphere and troposphere correction

➡ 1. 3D DRMS error of ephemeris is 0.2 m

➡ 2. Position can be estimated in accuracy of 0.2 m using CMAS SSR without ionosphere and troposphere correction

➡ CMAS SSR message is applicable for wide area PPP