Evaluation and Calibration of Receiver Inter-channel Biases for RTK-GPS/GLONASS

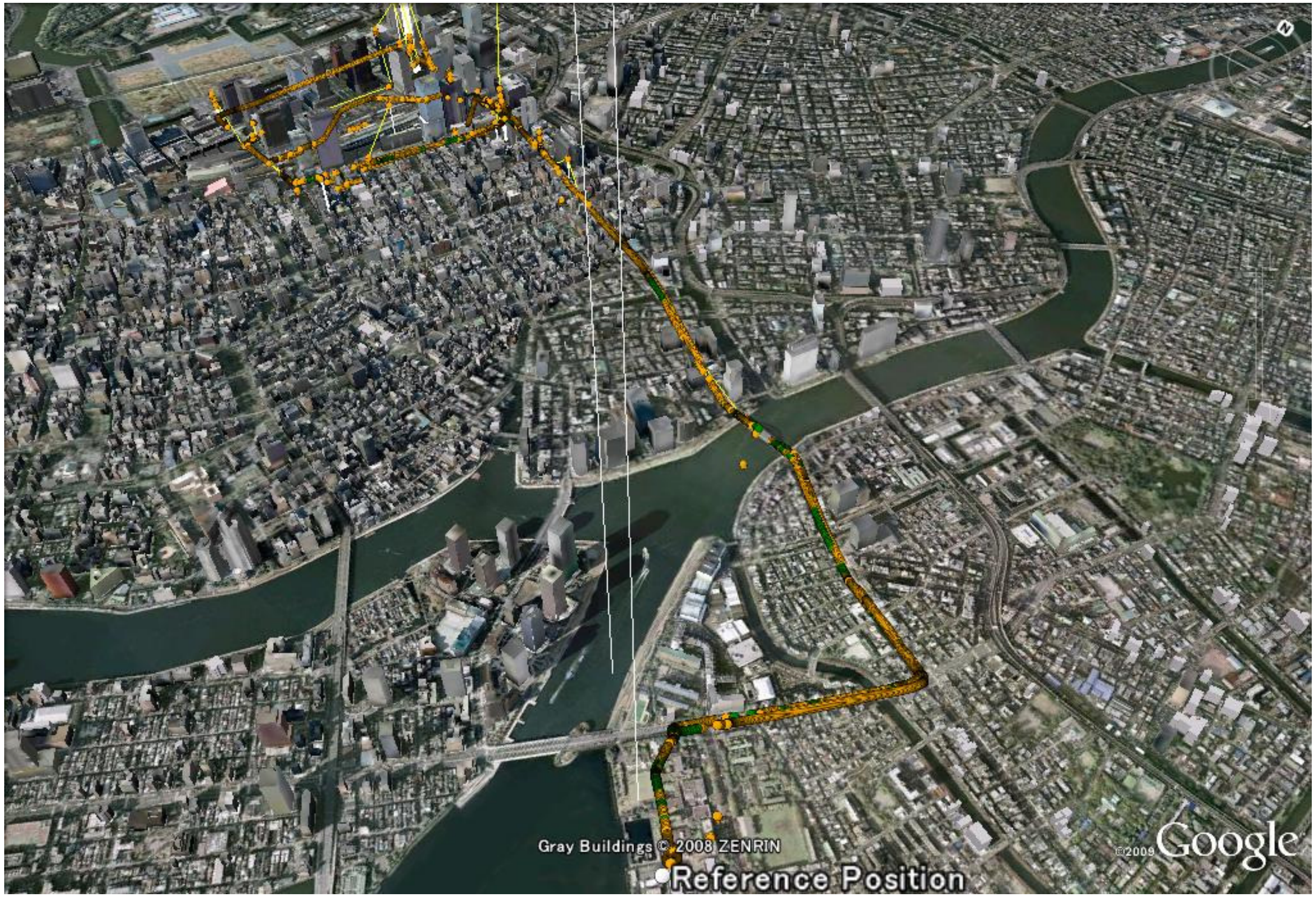
Hideki Yamada,
Tomoji Takasu, Nobuaki Kubo and Akio Yasuda
Tokyo University of Marine Science and Technology

Outline

- Background and Objective
- Inter-channel Bias Calibration
- RTK-GPS/GLONASS with Calibrated Biases
- Use of GLONASS Float Ambiguity
- Summary and Conclusions

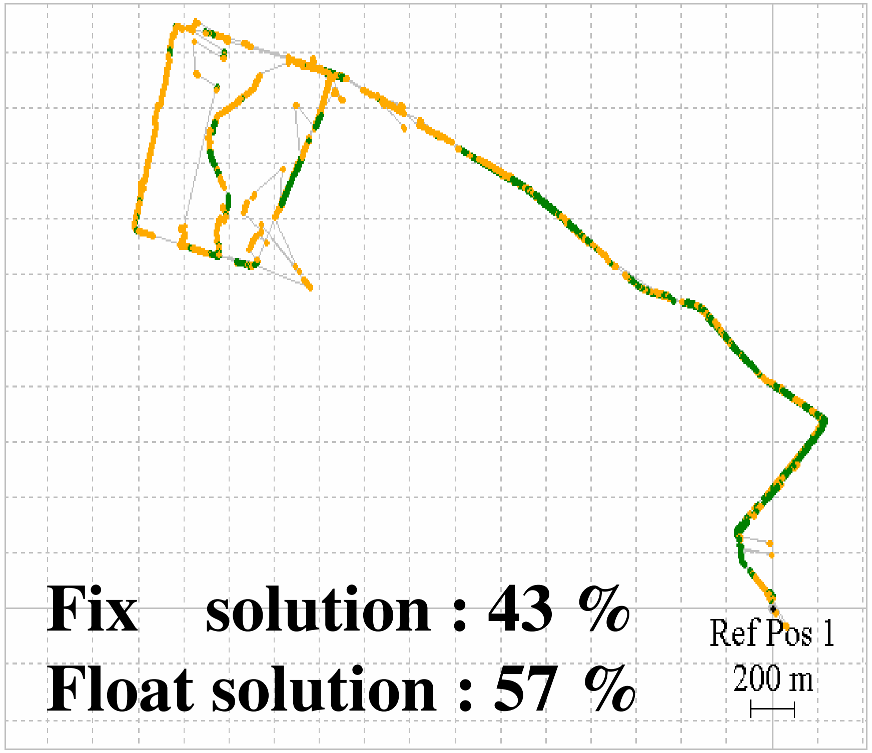
Mobile RTK Positioning

Instantaneous RTK (Real Time Kinematic) is precise positioning with epoch by epoch carrier-phase ambiguity resolution (AR).

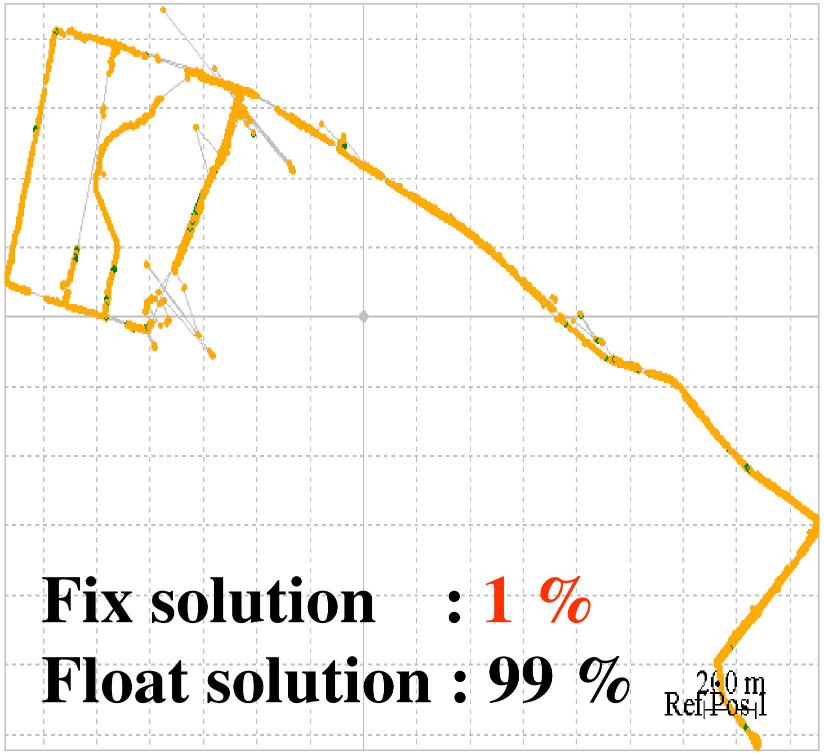


Results of Mobile RTK Positioning

NovAtel - NovAtel



NovAtel - JAVAD

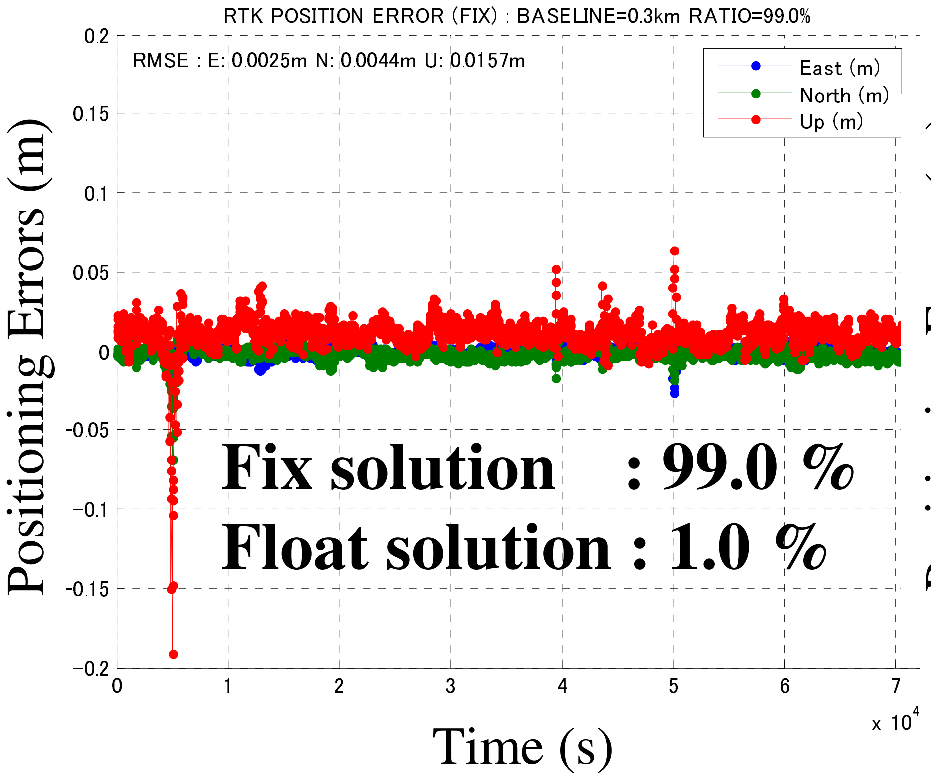


GPS + GLONASS L1 + L2

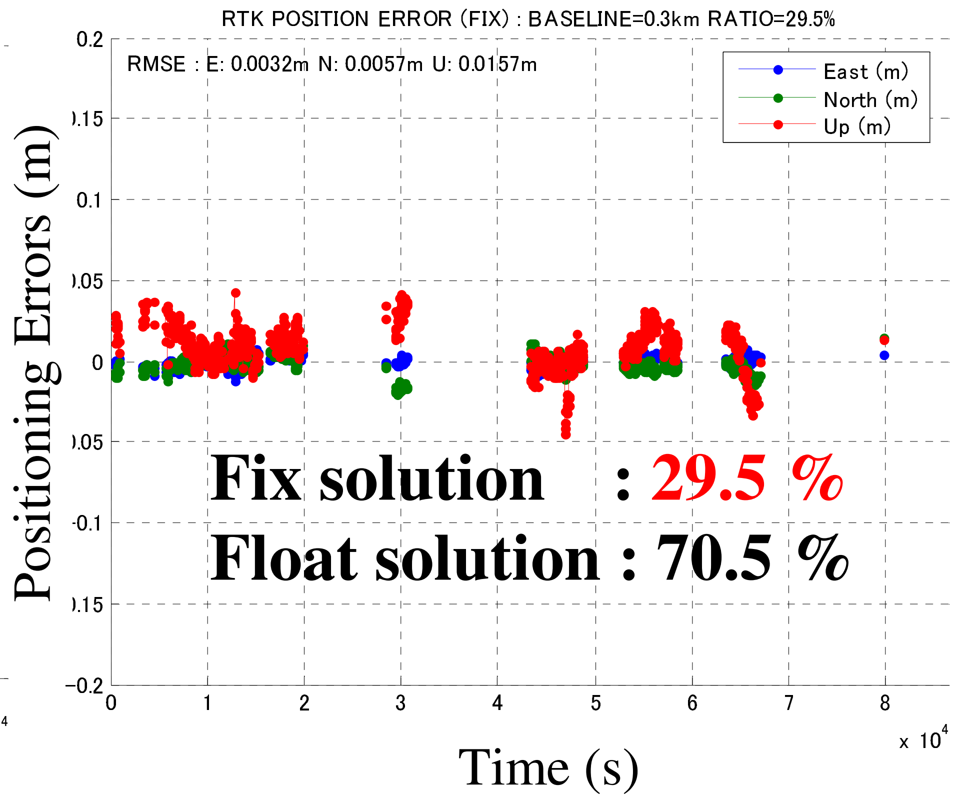
We aim to improve GLONASS positioning performance in RTK-GPS/GLONASS between different types of receivers.

Results of Static RTK Positioning

NovAtel -NovAtel



NovAtel - JAVAD



GPS + GLONASS L1 + L2 instantaneous AR

Base length = 300 m

Background and Objective

What is main source of observation errors to prevent GLONASS ambiguity from being fixed ?

Inter-channel bias

- The RF hardware design of a receiver will introduce frequency-dependent biases. These biases are known as an inter-channel bias.

- These biases can not be canceled out with double differencing between different types of receivers in GLONASS, except for GPS.

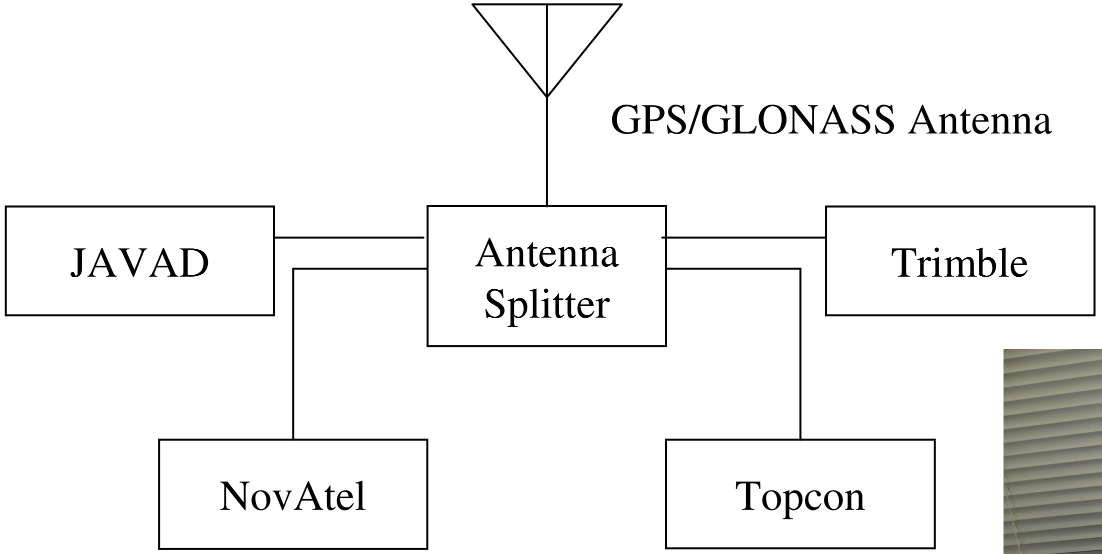
Background and Objective

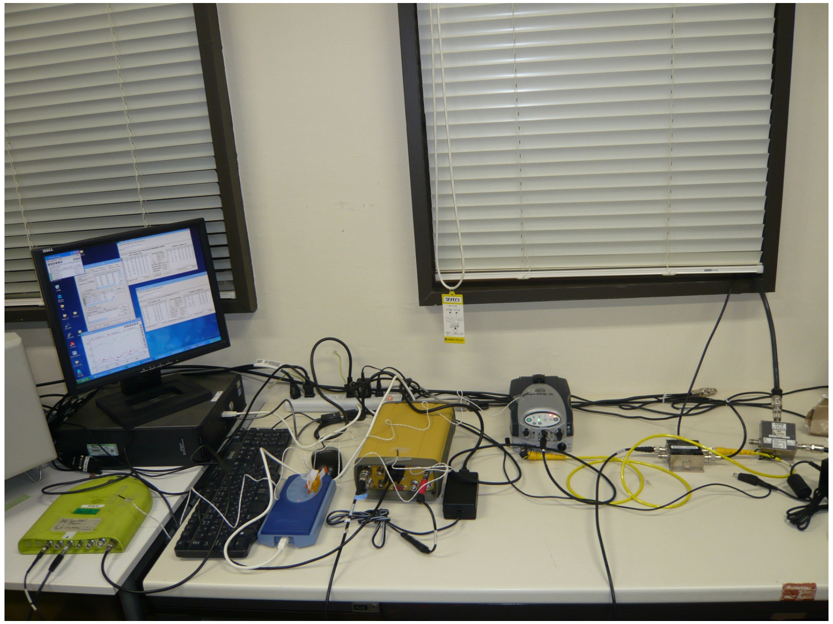
- Estimates of GLONASS inter-channel bias for several receivers are obtained in short baseline [Wanninger, L., et al, ION GNSS 2007].
- Narrow band loop filter smoothes SD residual to get on line code bias [Kozlov, D., et al, ION GNSS 2000].

- In this study, we try to improve the positioning performance of instantaneous RTK with off line tables of GLONASS inter-channel bias at various receivers calibrated in only zero baseline measurements.

Inter-channel Bias Calibration

Zero baseline test





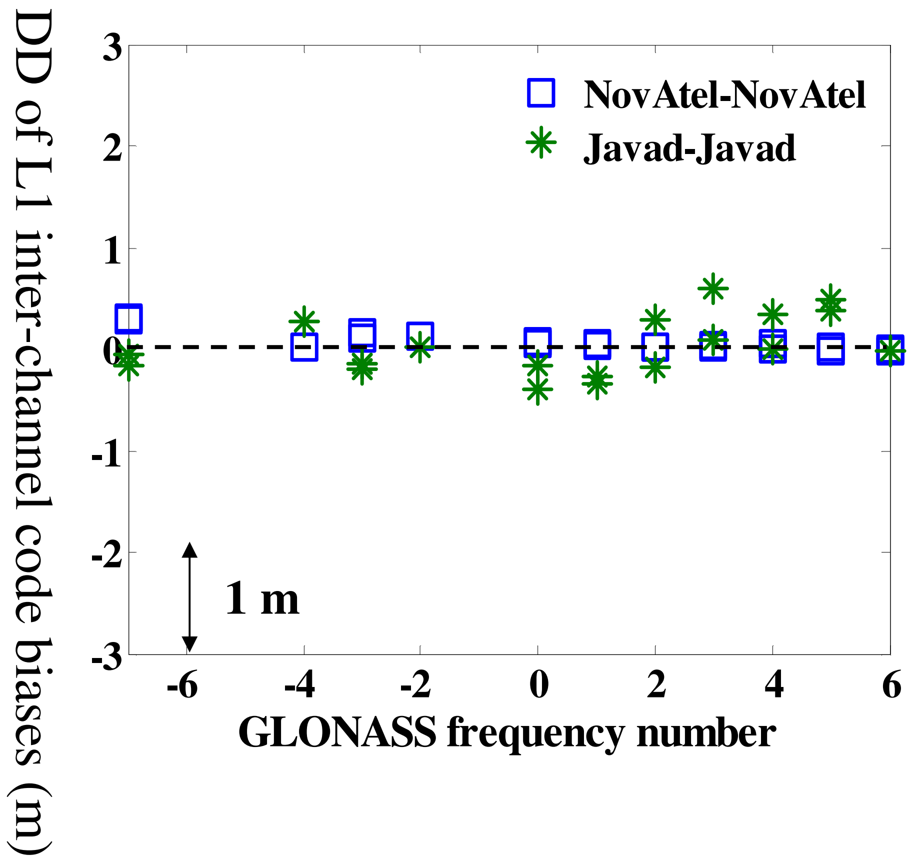
In the zero baseline, double-difference (DD) of code measurements can cancel out terms of orbital errors, clock errors, atmospheric delays and multipath, and remain DD of receiver noises and inter-channel biases.

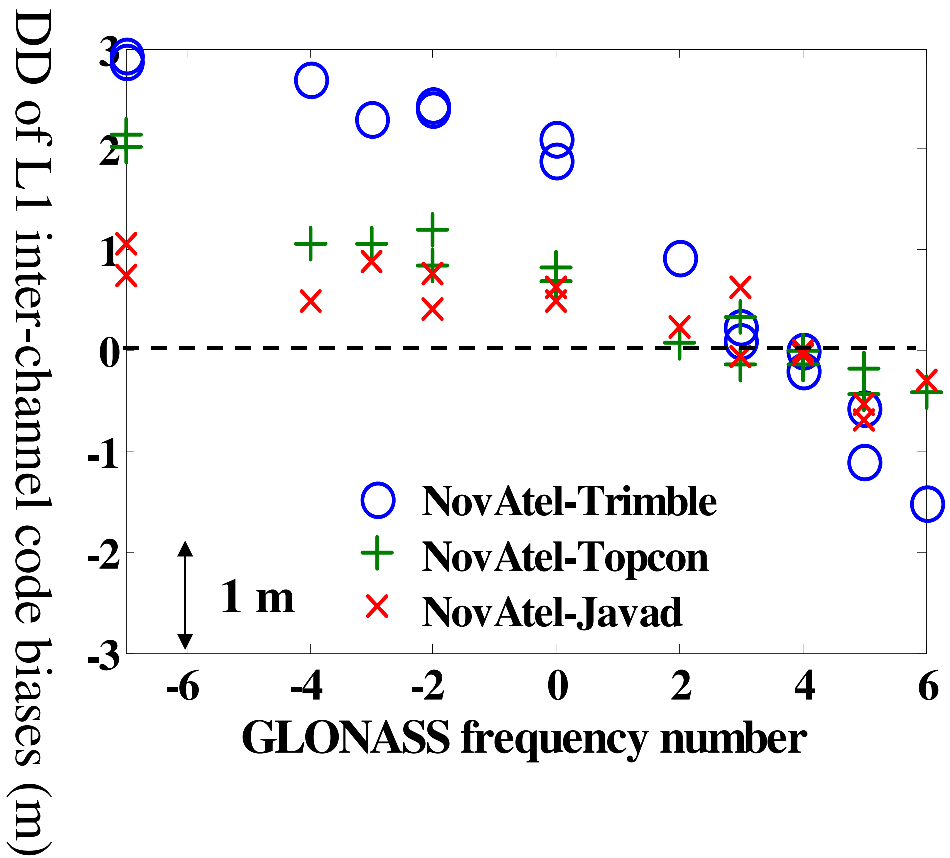
Inter-channel Bias Calibration

Experimental Environment

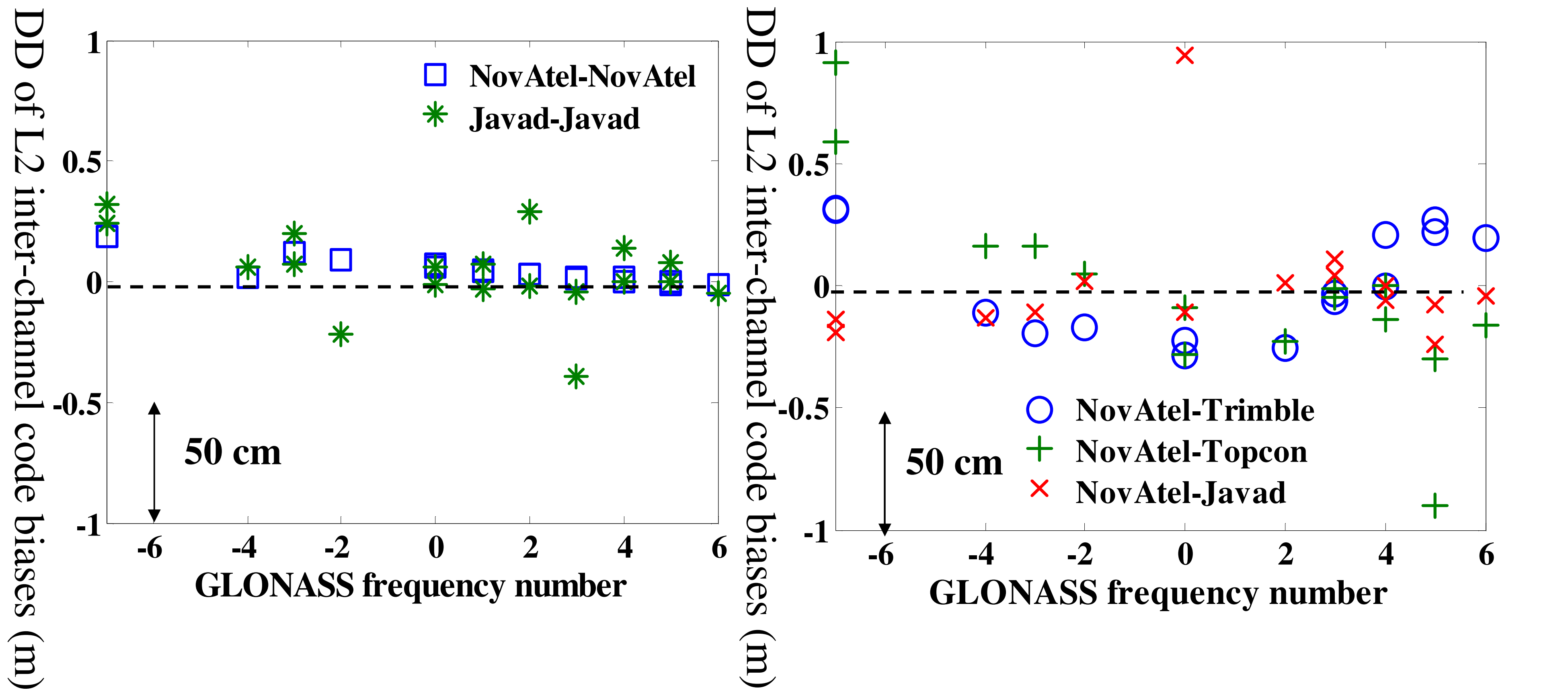
	JAVAD	NovAtel	Topcon	Trimble
Receiver type	Legacy	OEMV	NET-G3	R7GNSS
Antenna	Trimble (Zephyr 2)			
Site	Roof of our university (Open sky)			
Date	2009/12/23			
Total/interval	24 hours/30 s	20 hours/30 s	24 hours/30 s	24 hours/30 s

Calibrated L1 Inter-channel Code Biases
Tables of bias with slot 21





Calibrated L2 Inter-channel Code Biases
Tables of bias with slot 21



RTK-GPS/GLONASS with Calibrated Biases

1.GLONASS double difference equation

$$\Phi_{rb}^{ij} \equiv \lambda_i\left(\phi_r^i - \phi_b^i\right) - \lambda_j\left(\phi_r^j - \phi_b^j\right)$$

$$= \rho_{rb}^{ij} + N_{rb}^{ij} + \underline{d(\phi)_{rb}^{ij}} + mp(\phi)_{rb}^{ij} + \varepsilon(\phi)_{rb}^{ij}$$

$$P_{rb}^{ij} \equiv \left(p_r^i - p_b^i\right) - \left(p_r^j - p_b^j\right)$$

$$= \rho_{rb}^{ij} \underline{+ d(P)_{rb}^{ij}} + mp(P)_{rb}^{ij} + \varepsilon(P)_{rb}^{ij}$$

d(P) : inter-channel code bias, d ϕ : inter-channel carrier bias

Assumption on d(P) = d(ϕ)

2.Compensation by tables of biases

$$d_{rb}^{ij} = -d_{rb}^{si} + d_{rb}^{sj}$$

RTK Positioning

We evaluate positioning accuracy and fix rate of RTK-GPS/GLONASS in order to improve the GLONASS positioning performance by tables of bias.

RTK Processing Options

- **AR mode : Instantaneous AR (epoch by epoch)**

- **AR method : LAMBDA, ratio-test (threshold : 3)**

- **Base length :300 m**
(Rover: NovAtel, Javad. Base: NovAtel, Javad, Trimble,Topcon)

- **Date : 2009/12/23 24 h (epoch intervals 30 s)**

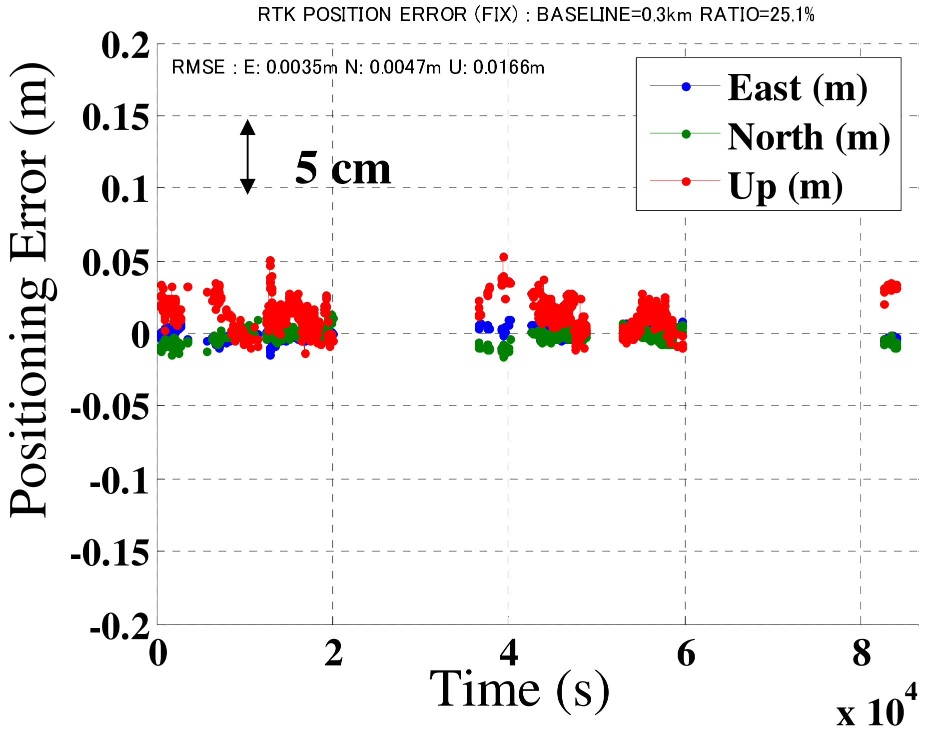
- **Elevation mask angle : 15 deg**

Positioning Results of RTK with GLONASS ambiguity fix solution

RTK-GPS/GLONASS L1 + L2

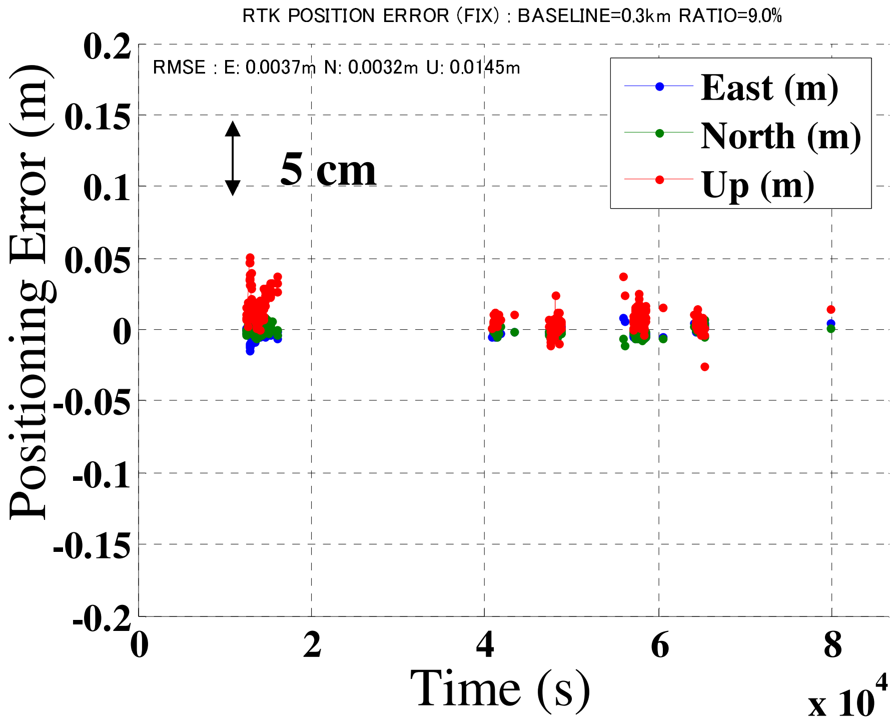
Baseline : NovAtel - Trimble

No correction



Fix rate 25.1 %

Correction with tables of biases



Fix rate 9.0 %

No improvement

Considerations

Why can not we fix GLONASS ambiguity by tables of inter-channel code bias ?

1.Estimation of d(ρ) has poor accuracy. 2. Assumption on d(ρ) = d(ϕ) might not be true.

→ Estimation of d ρ is producted by code measurements.

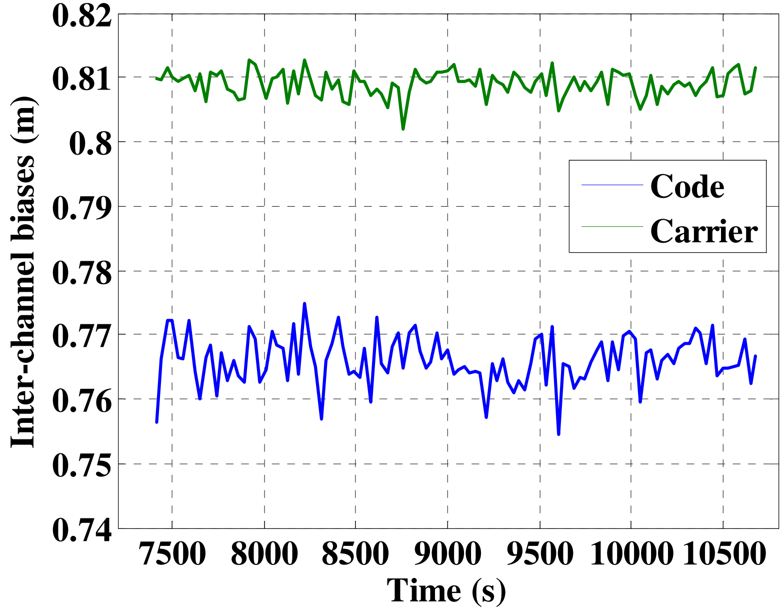
$$\Phi_{rb}^{ij} \equiv \lambda_i\left(\phi_r^i - \phi_b^i\right) - \lambda_j\left(\phi_r^j - \phi_b^j\right)$$

$$= \rho_{rb}^{ij} + N_{rb}^{ij} + d(P)_{rb}^{ij} + mp(\phi)_{rb}^{ij} + \varepsilon(\phi)_{rb}^{ij}$$

$$P_{rb}^{ij} \equiv \left(p_r^i - p_b^i\right) - \left(p_r^j - p_b^j\right)$$

$$= \rho_{rb}^{ij} + d(P)_{rb}^{ij} + mp(P)_{rb}^{ij} + \varepsilon(P)_{rb}^{ij}$$

The variation of inter-channel code and carrier biases (slot 23 - slot 7)



Inter-channel carrier bias can be obtained by subtracting the GLONASS integer ambiguity fixed in static mode from DD of carrier-phase measurement.

From the next slide, we try to evaluate the positioning performance of RTK-GPS/GLONASS with GLONASS ambiguity float solution.

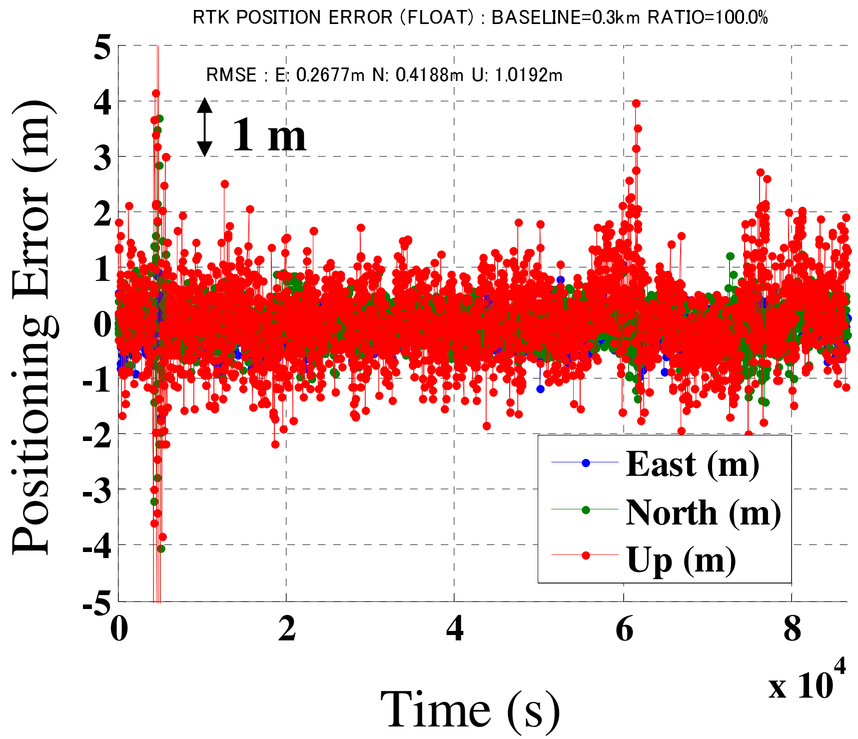
Use of GLONASS Float Ambiguity

Accuracy of float solution has an effect on the performance of ambiguity fixing.

We use GLONASS float ambiguity as the aid of GPS ambiguity resolution.

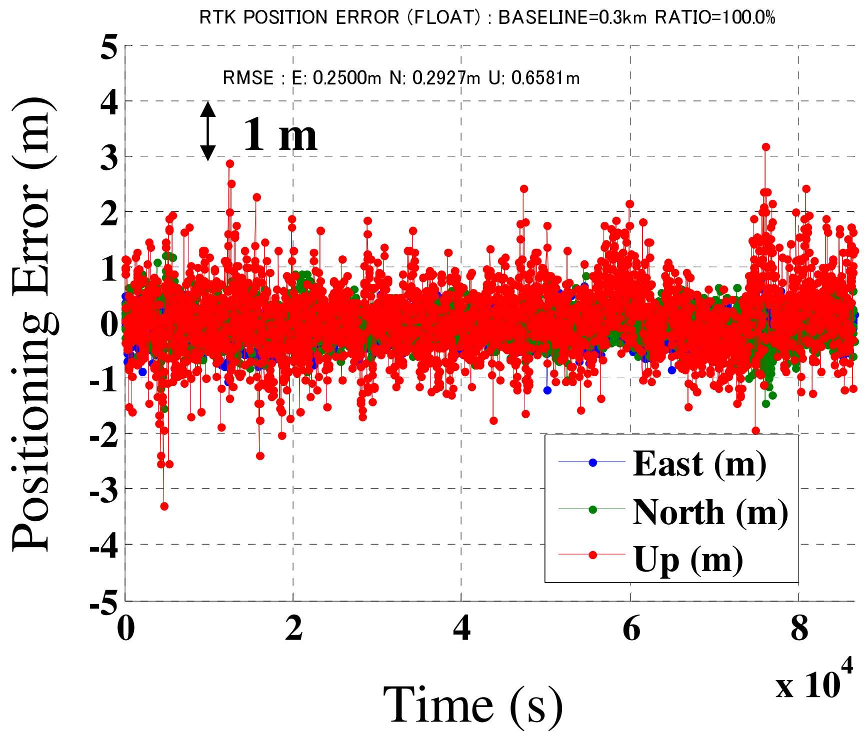
Float Solution

Only GPS



E/N/U (m) 0. 27/0.42/1.02

GPS + GLONASS



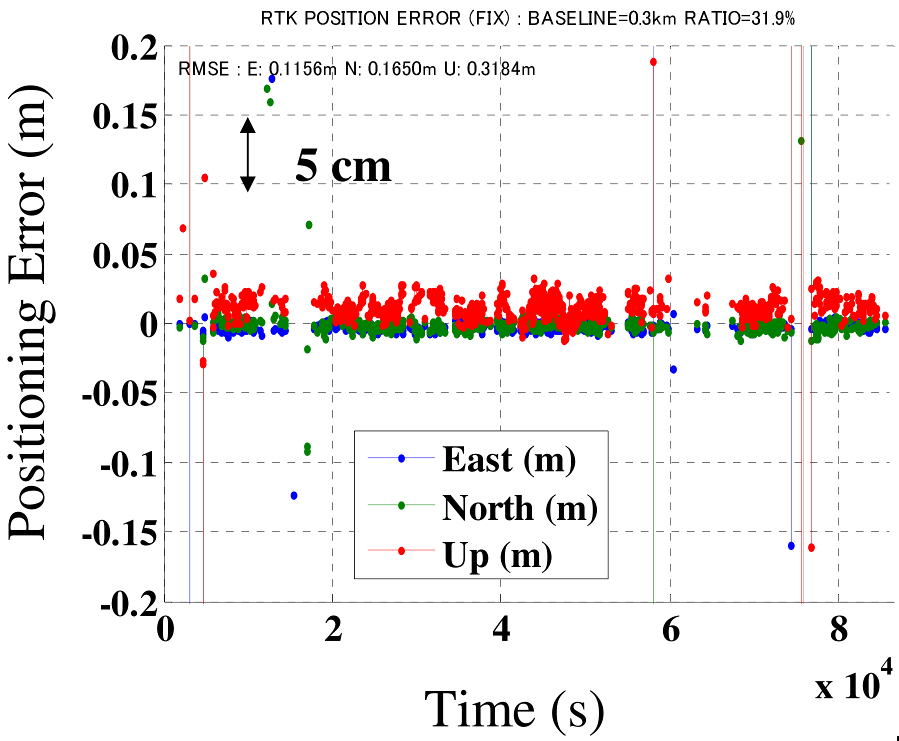
E/N/U (m) 0.25/0.29/0.65

Positioning Results of RTK with GLONASS ambiguity float solution

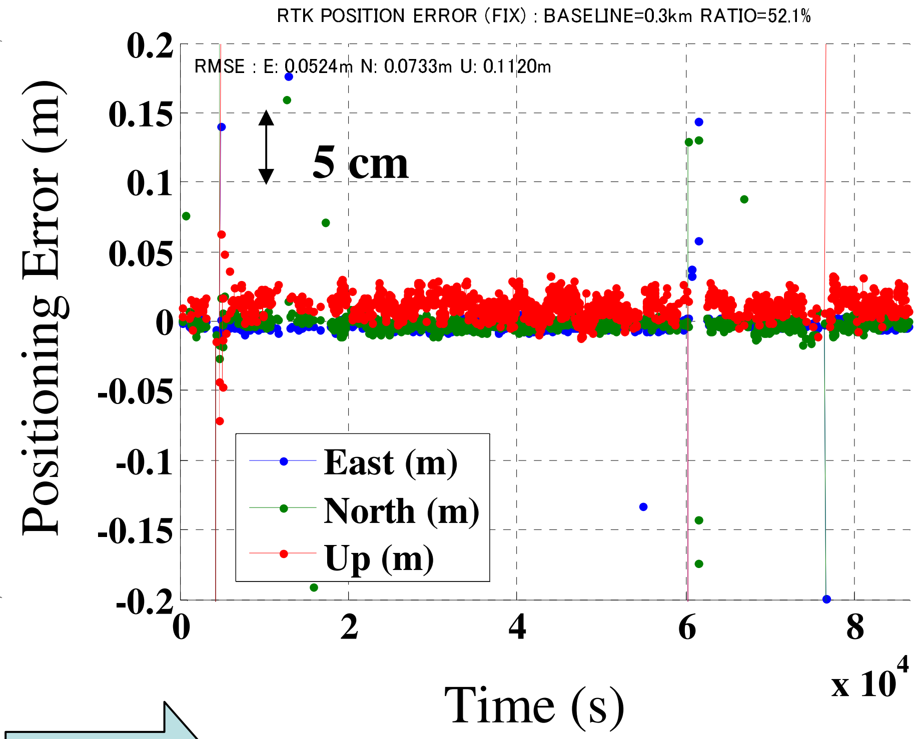
RTK-GPS/GLONASS L1

Baseline : NovAtel - Trimble

No correction



Correction with tables of bias



Fix rate : 31.9 %

E/N/U (m) : 0.12 /0.19/0.32

Fix rate : 52.1 %

E/N/U (m) : 0.05/0.07/0.11

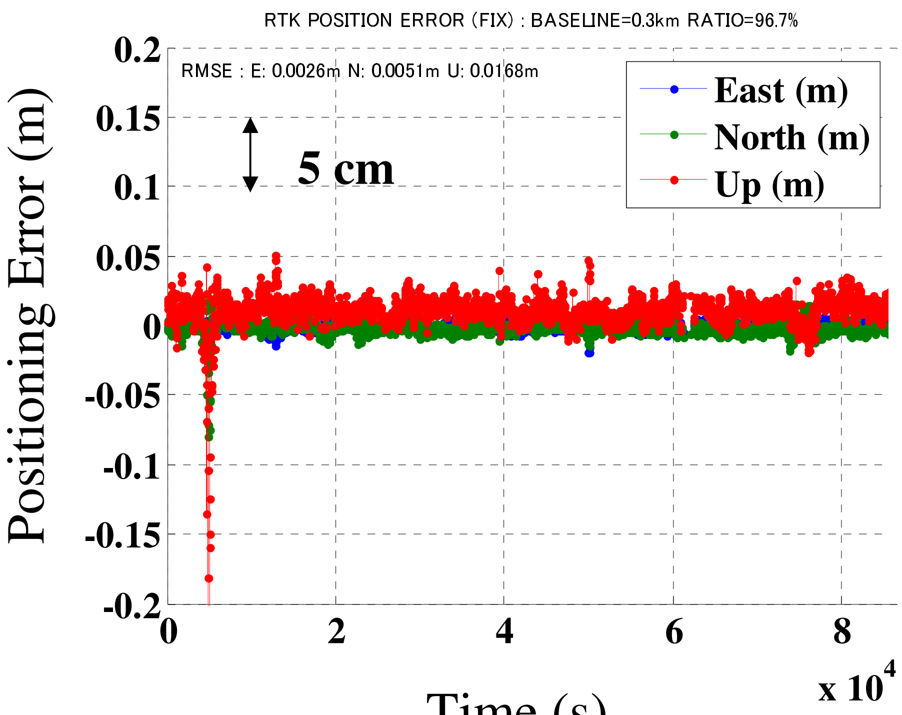
Improved by 20 %

Positioning Results of RTK with GLONASS ambiguity float solution

RTK-GPS/GLONASS L1 + L2

Baseline : NovAtel - Trimble

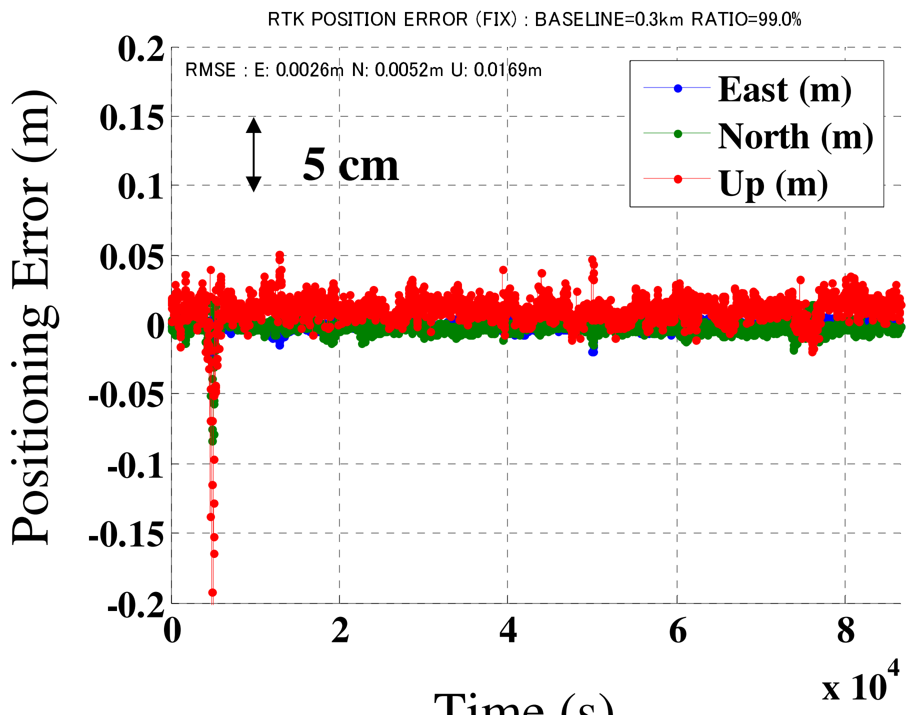
No correction



Fix rate : 96.7 %

E/N/U (m) : 0.01 /0.01/0.02

Correction with tables of bias



Fix rate : 99.0 %

E/N/U (m) : 0.01/0.01/0.02

Accuracy of RTK positioning with L1 measurements

Baseline 300 m	Only GPS	GPS + GLONASS (GLONASS float)	GPS + GLONASS (GLONASS float + bias)
	Fix rate	Fix rate	Fix rate
	E/N/U (m)	E/N/U (m)	E/N/U (m)
NovAtel -Trimble	49.5 %	31.9 %	52.1 %
	0.07/0.09/0.25	0.11/0.17/0.31	0.05/0.07/0.11
NovAtel - Topcon	45.5 %	41.5 %	47.0 %
	0.09/0.17/0.39	0.10/0.16/0.27	0.07/0.09/0.15
NovAtel - JAVAD	29.9 %	31.9 %	33.8 %
	0.13/0.21/0.54	0.12/0.17/0.40	0.11/0.18/0.35
JAVAD - Trimble	35.8 %	21.9 %	36.5 %
	0.12/0.14/0.32	0.17/0.23/0.53	0.10/0.11/0.30
JAVAD - Topcon	41.0 %	68.7 %	68.8 %
	0.09/0.11/0.32	0.04/0.06/0.14	0.04/0.06/0.14

Accuracy of RTK positioning with L1 + L2 measurements

Baseline 300 m	Only GPS	GPS + GLONASS (GLONASS float)	GPS + GLONASS (GLONASS float + bias)
	Fix rate	Fix rate	Fix rate
	E/N/U (m)	E/N/U (m)	E/N/U (m)
NovAtel - Trimble	98.9%	96.7%	99.0%
	0.01/0.01/0.02	0.01/0.01/0.02	0.01/0.01/0.02
NovAtel - Topcon	98.9%	96.4%	98.9%
	0.01/0.01/0.02	0.01/0.01/0.02	0.01/0.01/0.02
NovAtel - JAVAD	98.2%	98.0%	98.5%
	0.01/0.01/0.02	0.01/0.01/0.02	0.01/0.01/0.02
JAVAD -Trimble	98.1%	95.3%	97.0%
	0.01/0.01/0.02	0.01/0.01/0.02	0.01/0.01/0.02
JAVAD -Topcon	98.2%	98.0%	98.0%
	0.01/0.01/0.02	0.01/0.01/0.02	0.01/0.01/0.02

Summary and Conclusions

- We analysis and improve the performance degradation on GLONASS AR epoch by epoch.
- We can obtain tables of inter-channel biases with zero baseline test.
- Tables of inter-channel biases are effective in GLONASS ambiguity float solution.
- More precise calibration method of the biases is required for GLONASS Fixed ambiguity.

Future work

- Complete tables of inter-channel carrier bias as well as more precise code bias calibration
- Evaluate the difference between carrier and code bias