Multi-GNSS Opportunities and Challenges

Never Stand Still

School of Surveying & Spatial Information Systems

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Multi-GNSS
Opportunities and Challenges

- Introduction
- Opportunities
- Challenges and Solutions
- Concluding remarks

Introduction

GLONASS
FOC on
08/12/2011

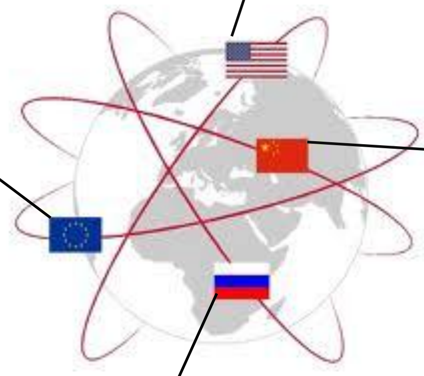
Source:gislounge.com

Introduction

FOC since July 1995

2 Operational
Satellites in Space
since Oct 2011

FOC on 2020



11 Operational
Satellites in Space
since Feb 2012

FOC on 2020

Source: kelloggreport.com

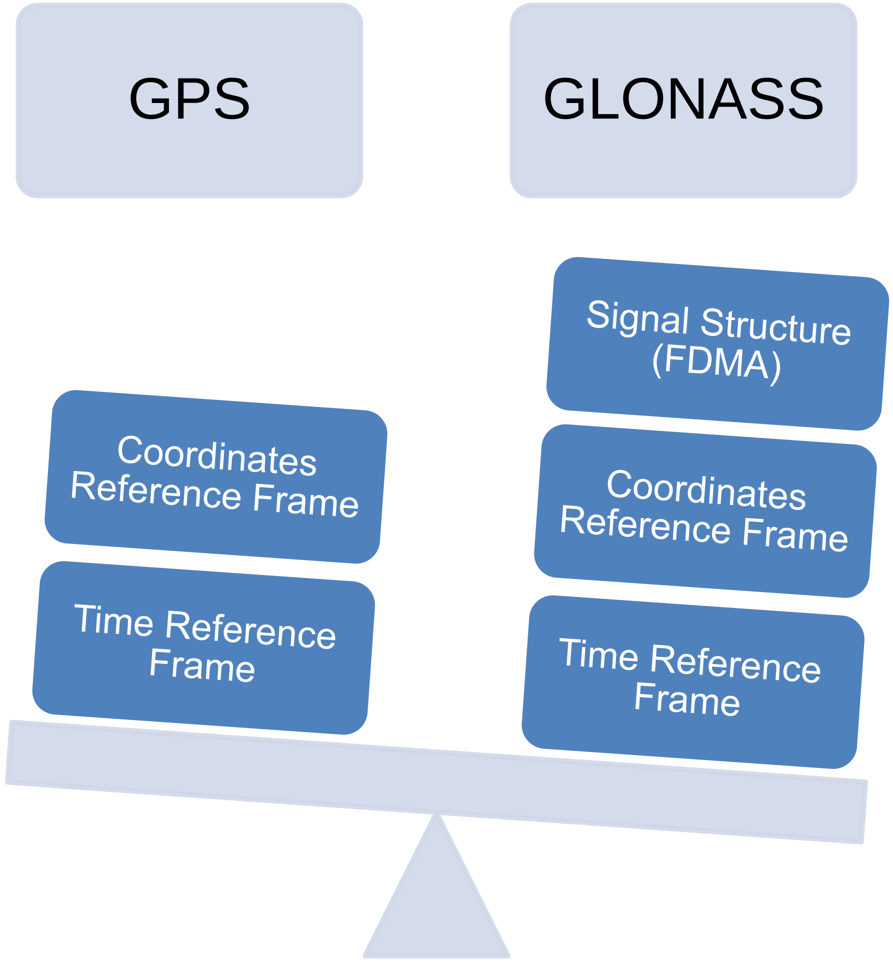
FOC since Dec 2011

http://www.colorado.edu/geography/gcraft/notes/gps/foc.txt
http://www.glonass-ianc.rsa.ru/en/
http://www.beidou.gov.cn/xtjs.html
http://www.esa.int/esaNA/galileo.html

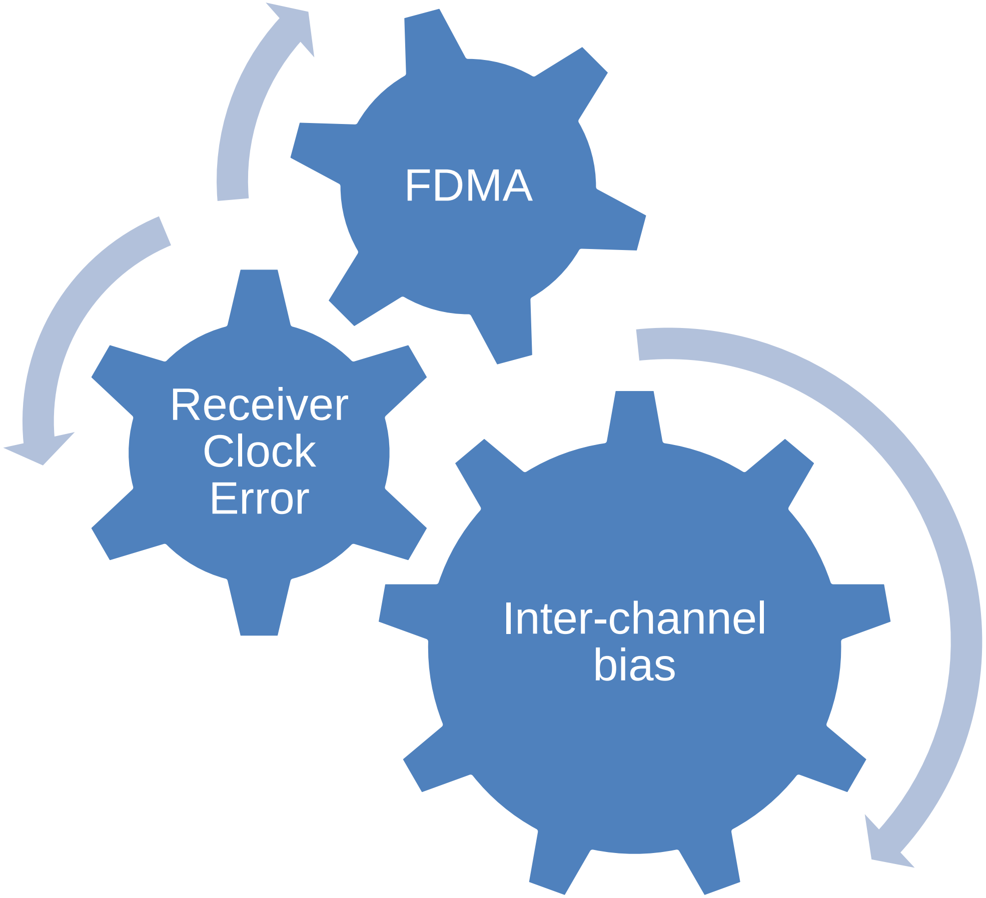
Opportunities

- Number of visible satellites increase >>> satellite geometry improves >>> positioning accuracy improves
- Increasing availability of GLONASS products from IGS analysis centres >>> real-time application becomes possible
- More and more GPS+GLONASS CORS networks >>> precise GNSS applications in post-mission and real-time

Challenges


GPS
GLONASS
Signal Structure (FDMA)
Coordinates Reference Frame
Time Reference Frame
Coordinates Reference Frame
Time Reference Frame

Challenges



Receiver Clock Error

- Estimation
- System 1

$$P_{rm,1}^{GPS,pq} = \rho_{rm,1}^{pq} + \varepsilon_{rm,1}^{pq}$$

$$P_{rm,1}^{GLO,x} = \rho_{rm,1}^{x} + cdt_{rm} + \varepsilon_{rm,1}^{x}$$

$$\varphi_{rm,1}^{GPS,pq} = \frac{f_1}{c}\rho_{rm,1}^{pq} + N_{rm,1}^{pq} + \tau_{rm,1}^{pq}$$

$$\varphi_{rm,1}^{GLO,xy} = \frac{f_1^x}{c}\rho_{rm,1}^{x} - \frac{f_1^y}{c}\rho_{rm,1}^{y} + \left(\frac{f_1^x}{c} - \frac{f_1^y}{c}\right)cdt_{rm} + N_{rm,1}^{xy} + \tau_{rm,1}^{xy}$$

- Elimination
- System 2

$$P_{rm,1}^{GPS,pq} = \rho_{rm,1}^{pq} + \varepsilon_{rm,1}^{pq}$$

$$P_{rm,1}^{GLO,xy} = \rho_{rm,1}^{xy} + \varepsilon_{rm,1}^{xy}$$

$$\Phi_{rm,1}^{GPS,pq} = \rho_{rm,1}^{pq} + \frac{c}{f_1}N_{rm,1}^{pq} + \tau_{rm,1}^{pq}$$

$$\Phi_{rm,1}^{GLO,xy} = \rho_{rm,1}^{pq} + \frac{c}{f_1^x}N_{rm,1}^{x} - \frac{c}{f_1^y}N_{rm,1}^{y} + +\tau_{rm,1}^{xy}$$

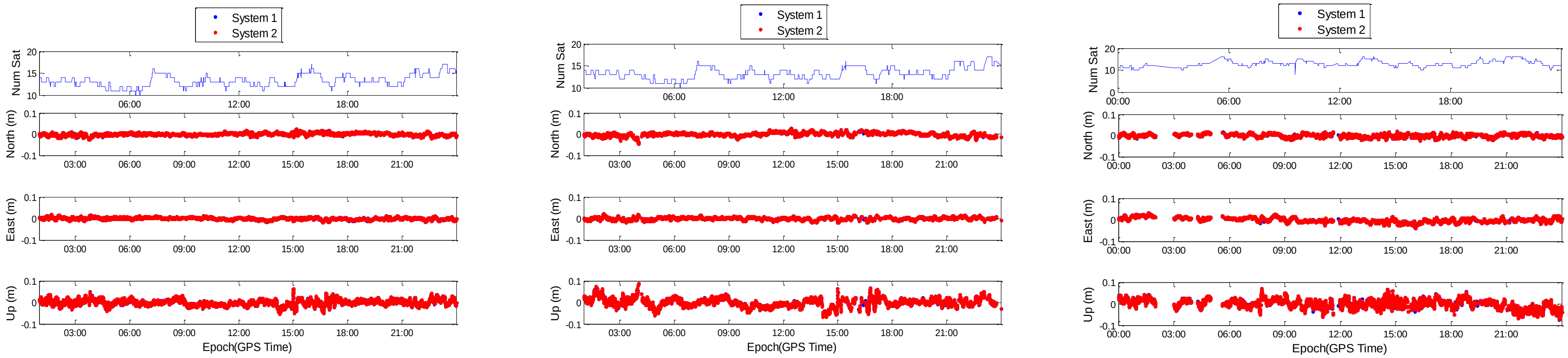
Receiver Clock Error

Summary of static RTK test parameters

	CHUN029	BTRG029	CHPB029
Data length	24 hr	24hr	24hr
Obs. Type	L1+L2	L1+L2	L1+L2
Baseline Length	4.4km	8.3km	9.7km
Receiver Types	Leica	Trimble	Leica
Elevation mask	15º	15º	15º
Interval	15s	15s	15s

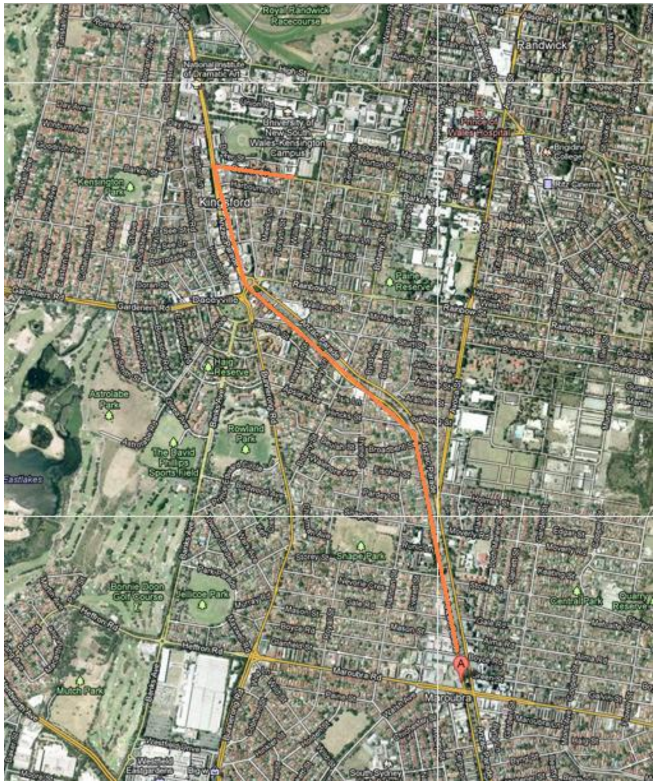
(29\12\2011)

Receiver Clock Error



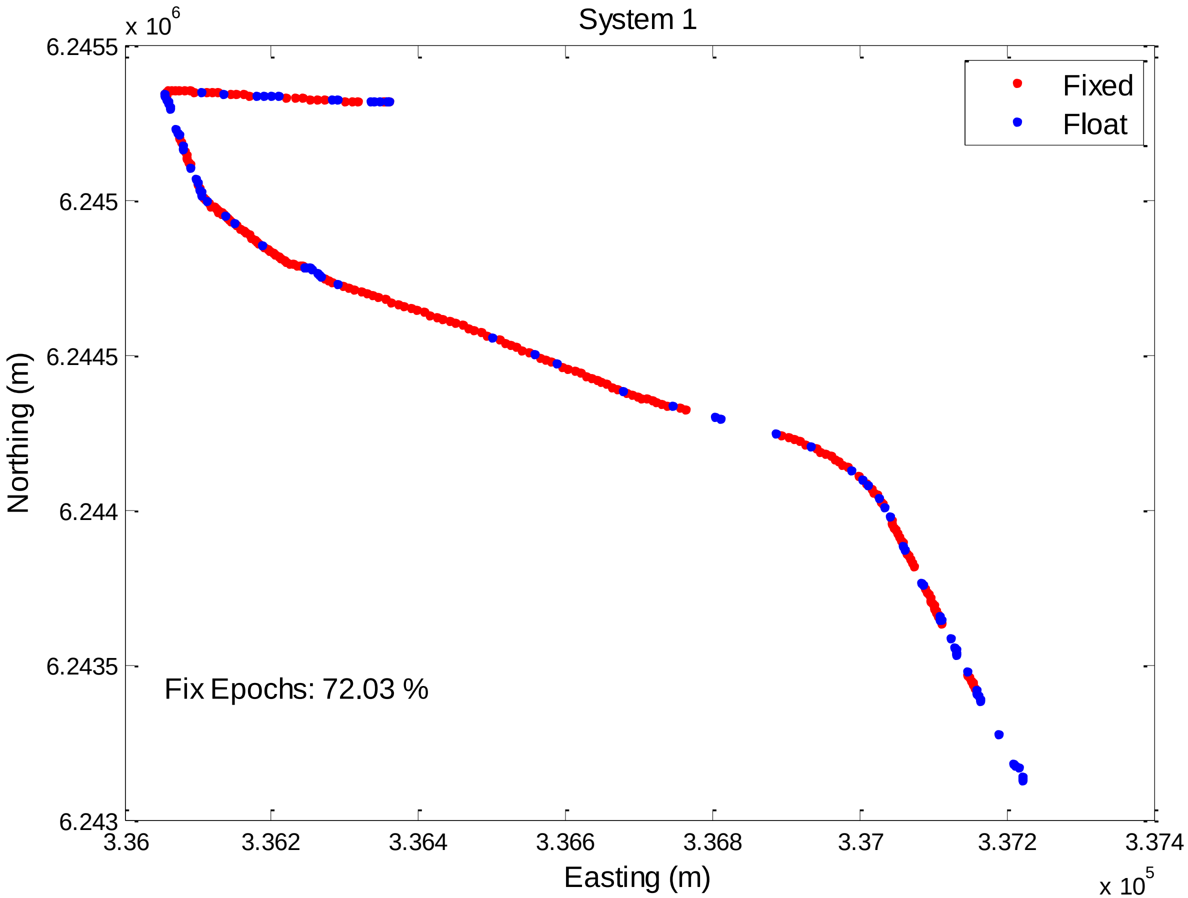
Baseline	*GPS-GLO model*	*Standard deviation (m)*		
		E	N	U
CHUN029	System 1	0.006	0.005	0.013
	System 2	0.006	0.005	0.013
BTRG060	System 1	0.007	0.010	0.021
	System 2	0.007	0.010	0.021
CHPB029	System 1	0.008	0.006	0.019
	System 2	0.008	0.006	0.019

Receiver Clock Error

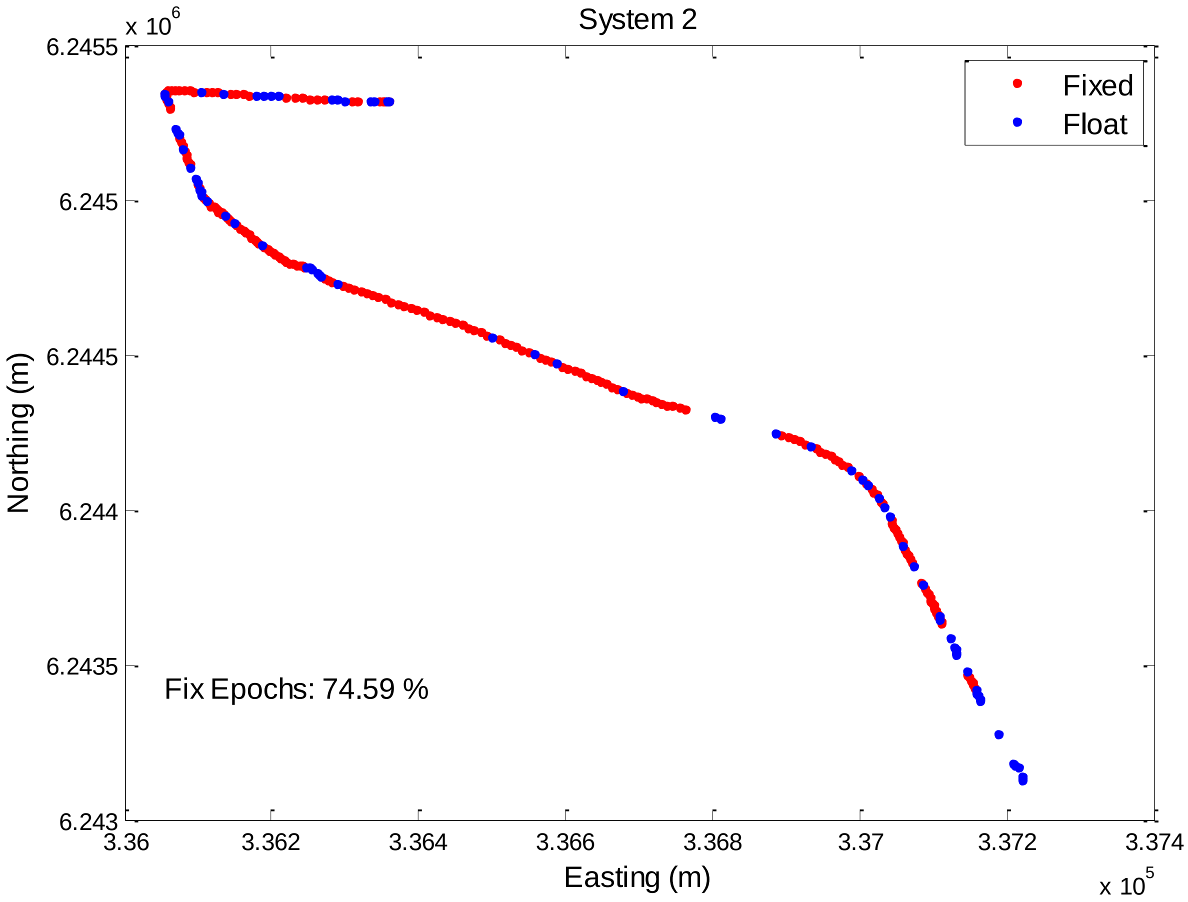


(21\12\2011)

Receiver Clock Error



Receiver Clock Error



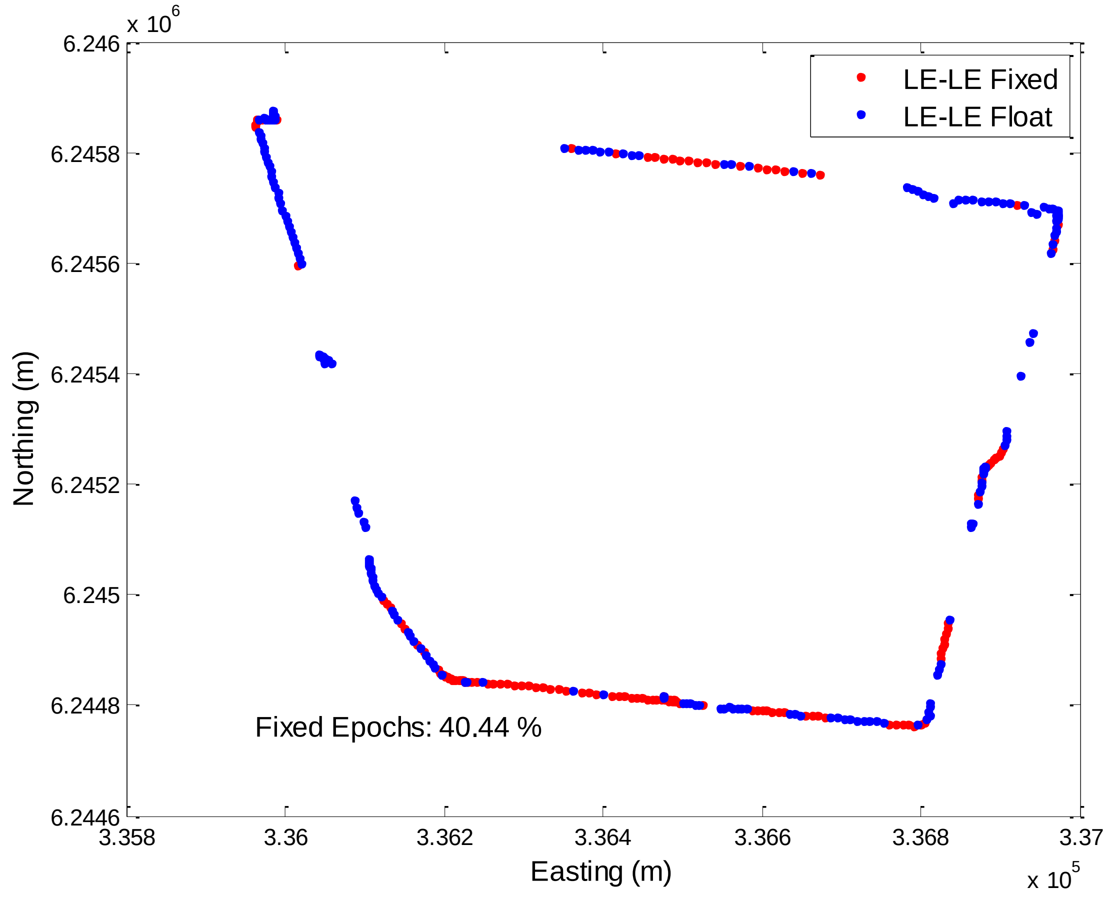
Inter-channel Bias

- Identification
- estimation
- calibration

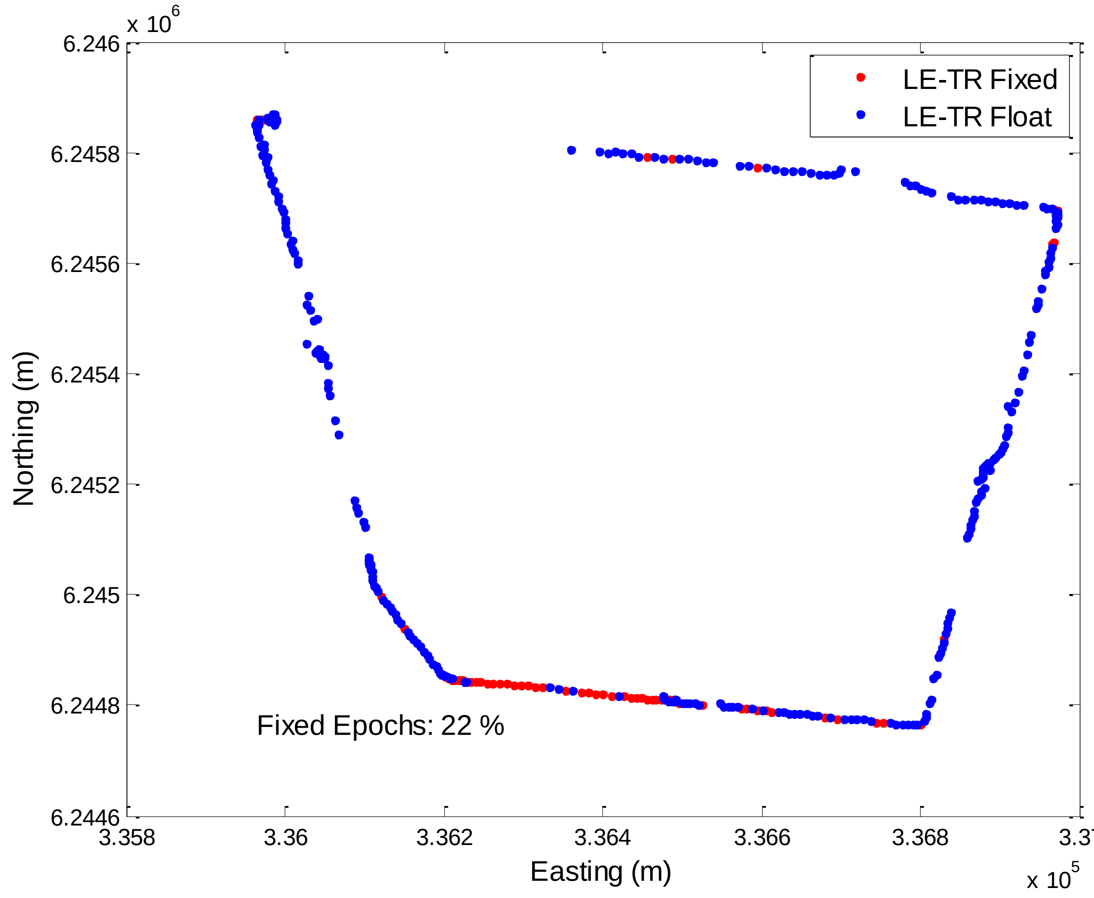
Inter-channel Bias - Identification

21/12/2011

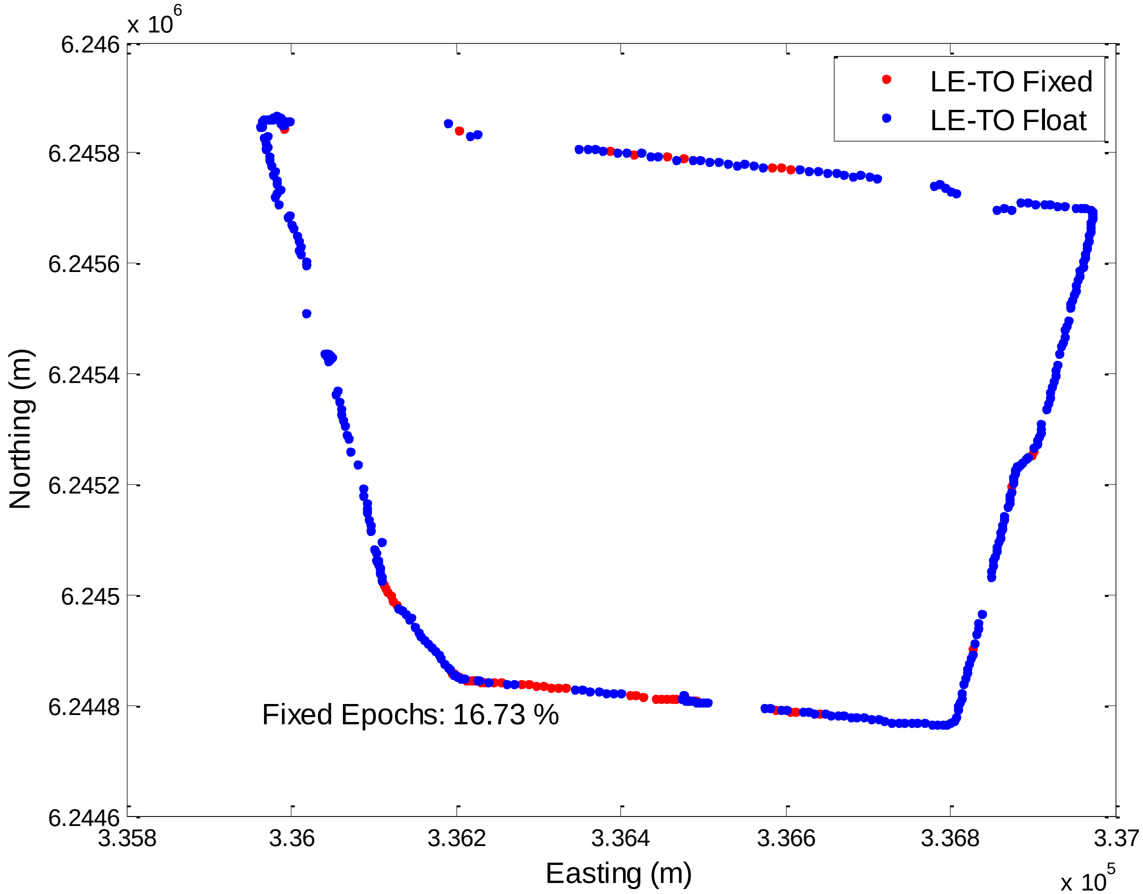
Inter-channel Bias - Identification



Inter-channel Bias - Identification



Inter-channel Bias - Identification



Inter-channel Bias - Estimation

(29\01\2012), 23hr, 15 sec

Inter-channel Bias - Estimation

$$P_{rm,1}^{GPS,pq} = \rho_{rm}^{pq} + \upsilon_{rm,1}^{pq}$$

$$P_{rm,1}^{GLO,pq} = \rho_{rm}^{pq} + \left(k^{p} - k^{q}\right) c\zeta_{rm} + \upsilon_{rm,1}^{pq}$$

$$\Phi_{rm,1}^{GPS,pq} = \rho_{rm}^{pq} + \frac{c}{f_1}\left(N_{rm,1}^{p} - N_{rm,1}^{q}\right) + \varepsilon_{rm,1}^{pq}$$

$$\Phi_{rm,1}^{GLO,pq} = \rho_{rm}^{pq} + \frac{c}{f_1^{\,p}} N_{rm,1}^{p} - \frac{c}{f_1^{\,q}} N_{rm,1}^{q} + \left(k^{p} - k^{q}\right) c\gamma_{rm} + \varepsilon_{rm,1}^{pq}$$

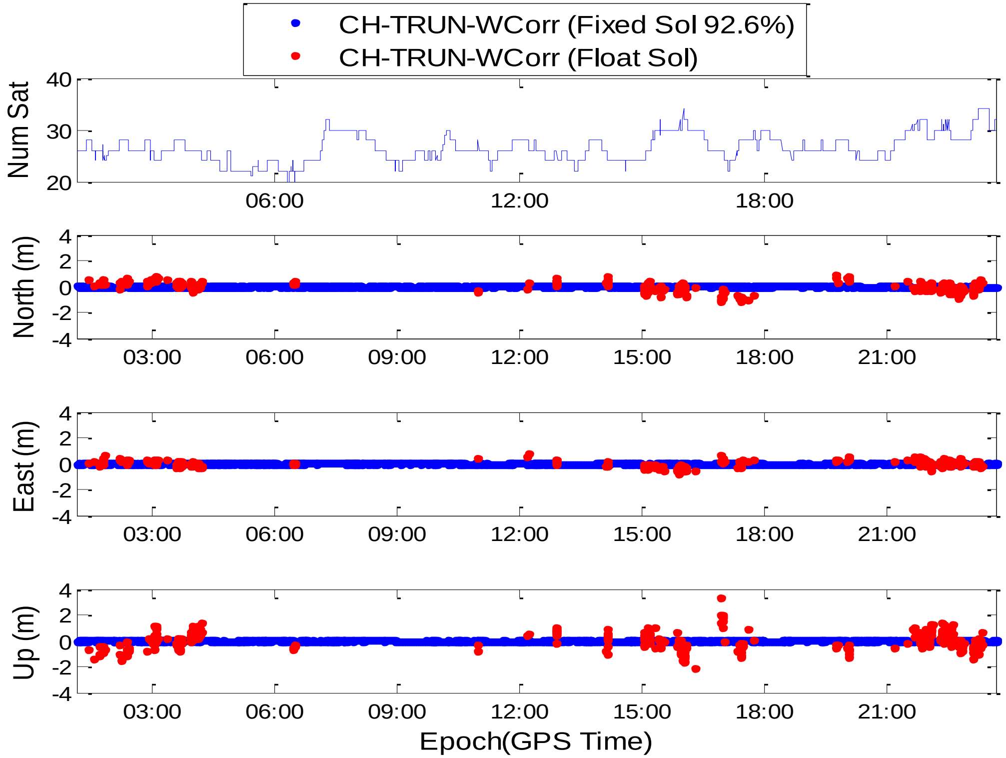
$c\gamma_{rm}$ CPH inter-channel bias expressed in metres by multiplying it by speed of light (c).

$c\zeta_{rm}$ PR inter-channel bias expressed in metres by multiplying it by speed of light (c).

GLONASS channel number for satellite (p) (-7~+6)

Average values of inter-channel bias between mixed receivers		
	LEICA - Trimble	LEICA - Topcon
CPH (m)	**-0.031**	**-0.024**
PR (m)	**-0.173**	**-0.115**

Inter-channel Bias - Calibration



LEICA-TRIMBLE	*Standard deviation (m)*		
	E	N	h
With Correction	0.006	0.005	0.013
Without Correction	0.242	0.193	0.568

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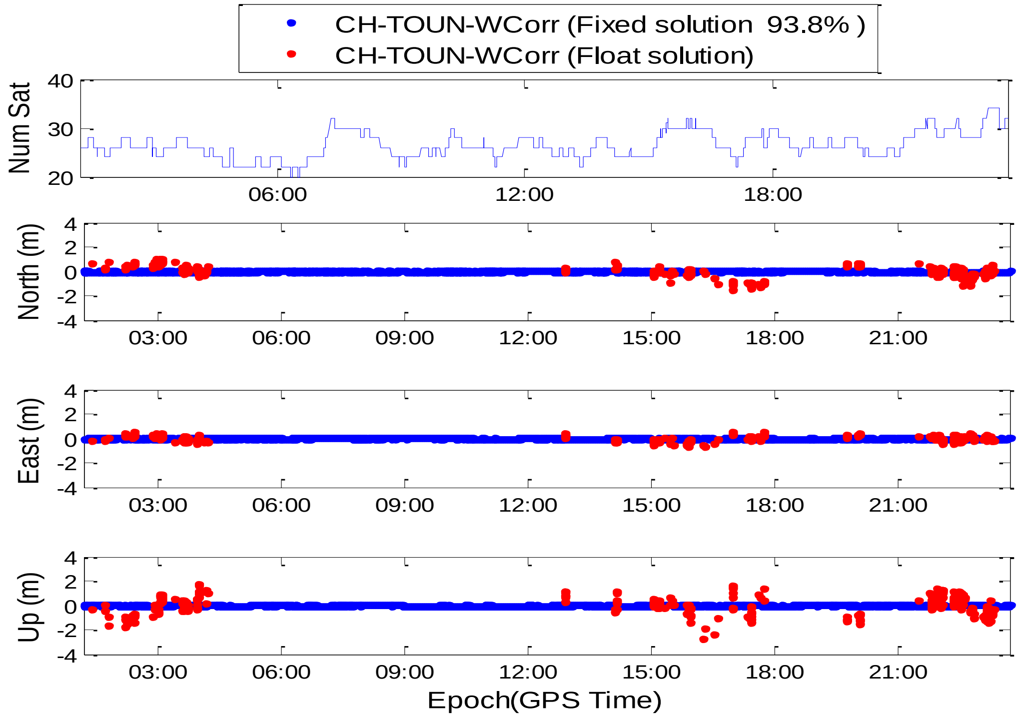
Inter-channel Bias - Calibration



LEICA-TOPCON	*Standard deviation (m)*		
	E	N	H
With Correction	0.006	0.005	0.013
Without Correction	0.344	0.206	0.702

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Concluding Remarks

- Will these challenges become a real obstacle to an “interoperable GNSS world”?????
  - Receiver clock error is well mitigated
  - Inter-channel bias still needs more attention from GNSS community.
- The answer may rely on a collaboration between GNSS analysis centres-academia-industry.