

2nd Asia Oceania Regional Workshop on GNSS 2010

**Development of an Open Source  
Multi-GNSS Data Processing Software**

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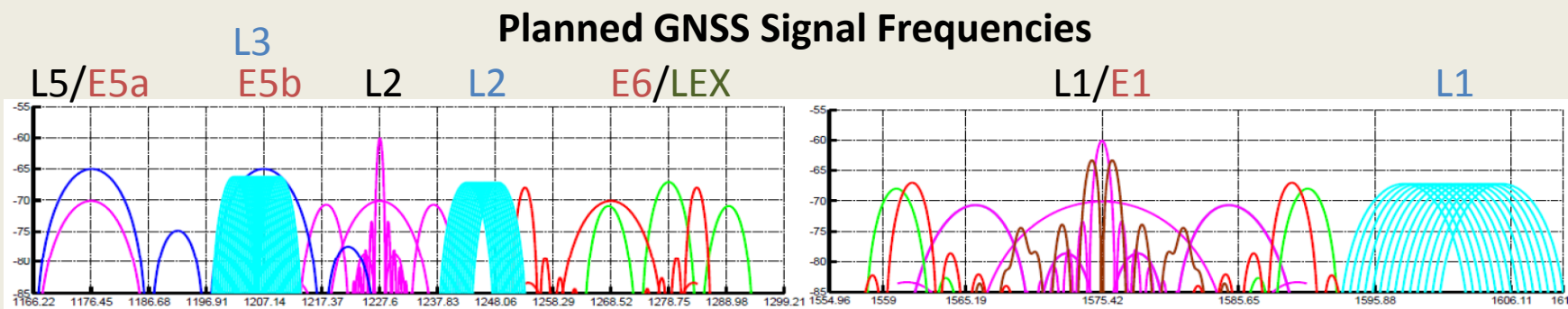
# Introduction

# GNSS

	System	Develop/ Operation	Satellite Orbit	G/R	Signals		Satellite Launch
					Frequency	MUX	
	<b>GPS</b>	US	MEO	G	L1,L2,L5	CDMA	1978-
	<b>GLONASS</b>	Russia	MEO	G	L1,L2(,L3)	FDMA (,CDMA)	1985-
	<b>Galileo</b>	EU	MEO	G	E1,E5,E6	CDMA	2011-
	<b>Compass</b>	China	MEO+GEO +IGSO	G	B1,B2,B3,L5	CDMA	2007-
	<b>QZSS</b>	Japan	IGSO	R	L1,L2,L5,LEX	CDMA	2010-
	<b>IRNSS</b>	India	GEO+IGSO	R	L5,S	CDMA	2013-?
	<b>SBAS</b>	US, ...	GEO	R	L1(,L5)	CDMA	-

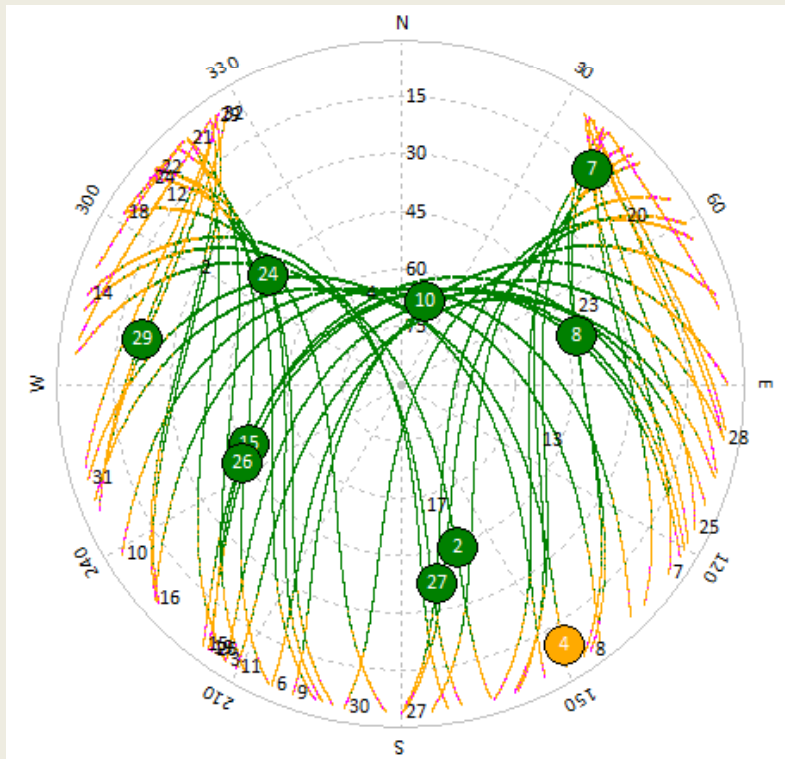
# Satellite Constellation

System	2010	2013	2016	2019
GPS	31 (+1)	32	32	32
GLONASS	23 (+3)	24 (+3)	24 (+3)	24 (+3)
Galileo	0	12	27 (+3)	27 (+3)
Compass	5	12	30	35
QZSS	1	3	3	3
IRNSS	0	7	7	7
SBAS	7	11	11	11
<b>Total</b>	<b>67</b>	<b>101</b>	<b>134</b>	<b>139</b>

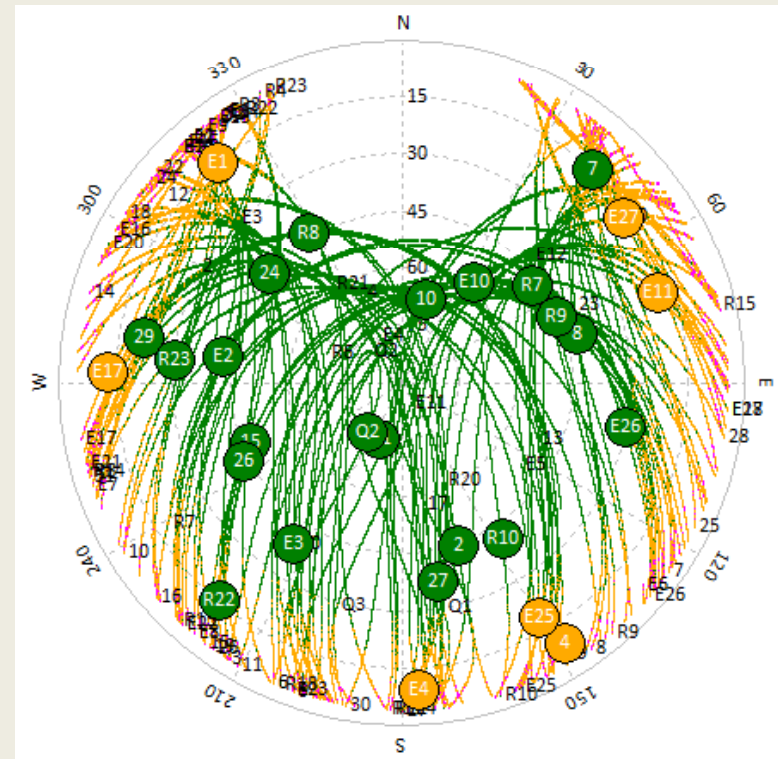


(Y.Yang, COMPASS: View on Compatibility and Interoperability, 2009)

# Many Visible Satellites



Only GPS



GPS+GLONASS+Galileo+QZSS

**We can obtain many benefits by using many GNSSs. However, we must handle complicated data with many signals.**

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# **Issues for Multi-GNSS Data Processing**

# Data Formats (1/2)

Formats	Data Type	GPS	GLO	GAL	QZSS	COMP	IRNSS	SBAS
RINEX 2	Raw OBS data	2.11	2.11	2.11	No	No	No	2.11
	Broadcast EPH	2.11	2.11	2.12	No	No	No	2.11
	SBAS Message	-	-	-	-	-	-	2.12
RINEX 3	Raw OBS data	3.00	3.00	3.00	No	No	No	3.00
	Broadcast EPH	3.00	3.00	3.00	No	No	No	3.00
	Precise Clock	3.00	3.00	No	No	No	No	No
BINEX	Raw OBS data	?	?	?	?	?	?	?
	Broadcast EPH	?	?	?	?	?	?	?
SP3	Precise EPH/CLK	3c	3c	3c	3c	3c	No	No
EMS	SBAS Message	-	-	-	-	-	-	2.0
ANTEX	Antenna PCV	1.3	1.3	1.4	1.4	1.4	1.4	1.4



## Data Formats (2/2)

Formats	Data Type	GPS	GLO	GAL	QZSS	COMP	IRNSS	SBAS
RTCM 2	DGPS Corr.	2.3	2.3	No	No	No	No	No
	Raw OBS data	2.3	2.3	No	No	No	No	No
	Broadcast EPH	2.3	2.3	No	No	No	No	No
RTCM 3	Raw OBS data	3.1	3.1	No	No	No	No	3.1
	Broadcast EPH	3.1	3.1	No	No	No	No	No
	Precise EPH	Draft	Draft	No	No	No	No	No
	Precise CLK	Draft	Draft	No	No	No	No	No
SBAS *	DGPS Corr.	C	C	No	No	No	No	C

\* RTCA/DO-229C

**Issue: Lack of standard data formats especially for newly coming GNSSs.**

# Time/Coordinate Systems

GNSS	Time System	Coordinate System
GPS	GPS Time	WGS84
GLONASS	GLONASS Time	PZ90.01
Galileo	Galileo System Time	GTRF
QZSS	QZSS Time	JGS
Compass	?	?
IRNSS	?	?
SBAS	Own System Time	Own Coordinate System

**Issue: How to get transformation parameters between different systems especially for time systems?**

# Satellite/Receiver Dependent Biases

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- Inter-code bias (DCB) in satellites
  - TGD, P1-P2, P1-C1, P2-C2, C1-C5, ...
- Inter-system bias in receivers
  - Receivers may introduce biases even in the same code
- Inter-channel bias for GLONASS
  - Receiver dependent bias due to FDMA
- Half or quarter cycle phase-shift
  - Between phase observables based on different code

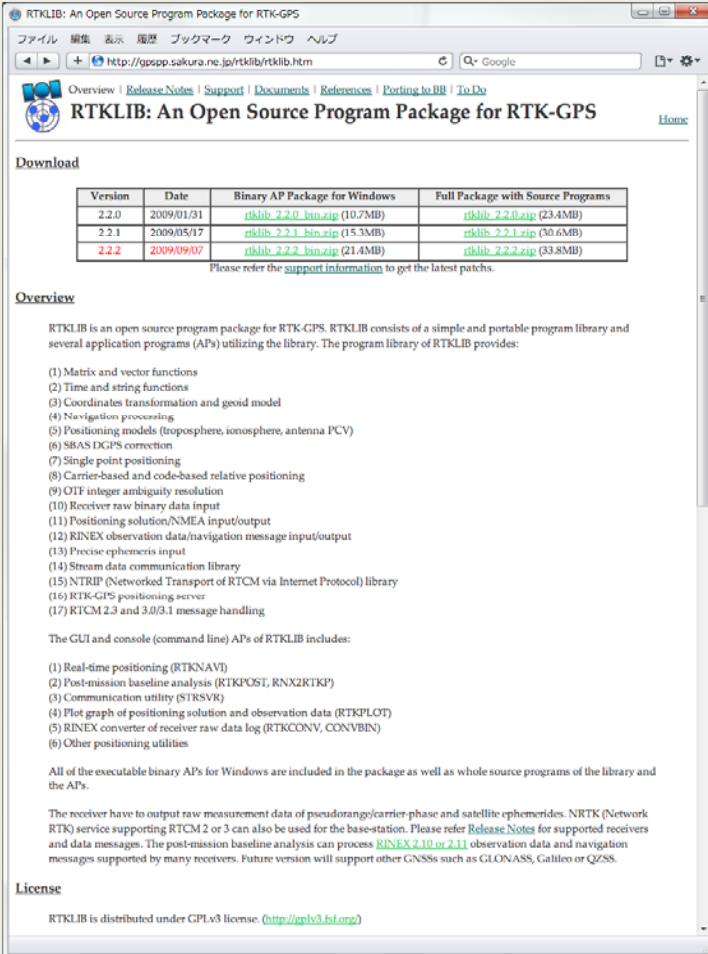
**Issue: How to handle such biases in processing the mixture of data from different GNSSs?**

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# **Multi-GNSS Implementation in RTKLIB**

# RTKLIB

- Open Source Program Package for GNSS Positioning
  - Whole source codes are freely available
  - License: GPLv3
  - >10,000 downloads (Total)
- Portable Library + Several APs
  - ANSI C + socket/pthread ...
  - Portable command-line APs
  - GUI APs for Windows



The screenshot shows the RTKLIB website with a navigation menu, a 'Download' section containing a table of versions, and an 'Overview' section listing various application programs (APs) and their features.

Version	Date	Binary AP Package for Windows	Full Package with Source Programs
2.2.0	2009/01/31	<a href="#">rtklib_2.2.0_bin.zip</a> (10.7MB)	<a href="#">rtklib_2.2.0.zip</a> (23.4MB)
2.2.1	2009/05/17	<a href="#">rtklib_2.2.1_bin.zip</a> (15.3MB)	<a href="#">rtklib_2.2.1.zip</a> (30.6MB)
2.2.2	2009/09/07	<a href="#">rtklib_2.2.2_bin.zip</a> (21.4MB)	<a href="#">rtklib_2.2.2.zip</a> (33.8MB)

Please refer the [support information](#) to get the latest patches.

### Overview

RTKLIB is an open source program package for RTK-GPS. RTKLIB consists of a simple and portable program library and several application programs (APs) utilizing the library. The program library of RTKLIB provides:

- (1) Matrix and vector functions
- (2) Time and string functions
- (3) Coordinates transformation and geoid model
- (4) Navigation processing
- (5) Positioning models (troposphere, ionosphere, antenna PCV)
- (6) SBAS DGPS correction
- (7) Single point positioning
- (8) Carrier-based and code-based relative positioning
- (9) OIF integer ambiguity resolution
- (10) Receiver raw binary data input
- (11) Positioning solution/NMEA input/output
- (12) RINEX observation data/navigation message input/output
- (13) Precise ephemeris input
- (14) Stream data communication library
- (15) NTRIP (Networked Transport of RTCM via Internet Protocol) library
- (16) RTK-GPS positioning server
- (17) RTCM 2.3 and 3.0/3.1 message handling

The GUI and console (command line) APs of RTKLIB includes:

- (1) Real-time positioning (RTKNAVI)
- (2) Post-mission baseline analysis (RTKPOST, RNX2RTKP)
- (3) Communication utility (STRSVK)
- (4) Plot graph of positioning solution and observation data (RTKPLOT)
- (5) RINEX converter of receiver raw data log (RTKCONV, CONVBIN)
- (6) Other positioning utilities

All of the executable binary APs for Windows are included in the package as well as whole source programs of the library and the APs.

The receiver have to output raw measurement data of pseudorange/carrier phase and satellite ephemerides. NRTK (Network RTK) service supporting RTCM 2 or 3 can also be used for the base-station. Please refer [Release Notes](#) for supported receivers and data messages. The post-mission baseline analysis can process [RINEX 2.10 or 2.11](#) observation data and navigation messages supported by many receivers. Future version will support other GNSSs such as GLONASS, Galileo or QZSS.

### License

RTKLIB is distributed under GPLv3 license. (<http://gpslib.fsf.org/>)

<http://www.rtklib.com>

# Brief History

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- 2006/4 v.0.0.0 First version for RTK+C Programming lecture
- 2007/1 v.1.0.0 Simple post processing AP for KGPS
- 2007/3 v.1.1.0 Add windows GUI AP
- 2008/7 v.2.1.0 Add APs, support medium-range
- 2009/1 v.2.2.0 Add real-time AP, support NTRIP  
Distributed as Open Source S/W
- 2009/5 v.2.2.1 Support RTCM, NRTK, several receivers
- 2009/9 v.2.2.2 Fix bugs, provide English manual
- 2009/12 v.2.3.0 Support GLONASS
- 2010/8 v.2.4.0 Support PPP, RINEX 3

# RTKLIB APs

The image displays several windows from the RTKLIB software suite:

- STRSVR**: A window showing stream configuration with columns for Stream, Type, Opt. Ord, Bytes, and Ops. It lists (0) Input as NTRIP Client and (1) Output as Serial.
- RTKCONV**: A window for converting observation files, showing time start/end (SPST) and interval settings, and a list of receiver log files.
- NTRIPBROWS**: A window showing a table of NTRIP sources. The table includes columns for Mountpoint, ID, Format, Format-Details, Cn, and New-System/Network.
- RTKNAVI**: A window displaying a solution for SBAS, including coordinates (N: 35° 52' 22.7486", E: 138° 23' 22.7875", H: 961.418 m) and a bar chart showing rover SNR.
- RTKPOST**: A window for post-processing, showing observation data, navigation messages, and base station observation data.
- RTKPLOT**: A window showing a 2D plot of a trajectory with a green line on a grid. The plot includes a scale bar and coordinate information.

# Features of RTKLIB

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- Standard and precise positioning algorithms with:
  - GPS, GLONASS, SBAS (and Galileo, QZSS)
- Various positioning modes:
  - Single, SBAS, DGPS, RTK, Static, Moving-base and PPP
- Supports many formats/protocols and receivers:
  - RINEX 2, RINEX 3, RTCM v.2, RTCM v.3, NTRIP 1.0, NMEA0183, SP3, RINEX CLK, ANTEX, NGS PCV, ...
  - NovAtel, Hemisphere, u-blox, SkyTraq, ...
- External communication via:
  - Serial, TCP/IP, NTRIP and file streams



# RTKLIB 2.4.0

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- Released on August 8, 2010
- New Features:
  - PPP-Kinematic or PPP-Static mode for both of real-time and post-processing
  - Long baseline RTK up to 1,000 km
  - Supports RTCM v.3 MT1057-1068 (SSR) for real-time orbit and clock corrections
  - Supports RINEX 3.0 for multi-GNSS processing
  - Ready to support new GNSS (QZSS, Galileo, ...)
  - Real-time and remote visualization by RTKPLOT

# Supported RINEX File Types

RINEX Version	Observation Data (OBS)							MET
	GPS	GLO	GAL	QZSS	COMP	IRNSS	SBAS	
2.10,11,12	O	O	O	O*	-	-	O	-
3.00	O	O	O	O*	-	-	O	-

RINEX Version	Navigation Messages (NAV)							CLK
	GPS	GLO	GAL	QZSS	COMP	IRNSS	SBAS	
2.10,11,12	N	G	L*	J*	-	-	H	-
3.00	N	N	N	N*	-	-	N	C**

\* extension, \*\* read only, - not supported

# Supported OBS Types for RINEX 3

Type: Signal	(GNSS)	Type: Signal	(GNSS)
L1C	: L1C/A, E1C (GPS, GLO, GAL, QZS, SBS)	L2Y	: L2Y (GPS)
L1P	: L1P (GPS, GLO)	L2M	: L2M (GPS)
L1W	: L1 Z-track (GPS)	L2N	: L2codeless (GPS)
L1Y	: L1Y (GPS)	L5I	: L5/E5aI (GPS, GAL, QZS, SBS)
L1M	: L1M (GPS)	L5Q	: L5/E5aQ (GPS, GAL, QZS, SBS)
L1N	: L1codeless (GPS)	L5X	: L5/E5aI+Q (GPS, GAL, QZS, SBS)
L1S	: L1C(D) (GPS, QZS)	L7I	: E5bI (GAL)
L1L	: L1C(P) (GPS, QZS)	L7Q	: E5bQ (GAL)
L1E	: L1-SAIF (QZS) *	L7X	: E5bI+Q (GAL)
L1A	: E1A (GAL)	L6A	: E6A (GAL)
L1B	: E1B (GAL)	L6B	: E6B (GAL)
L1X	: E1B+C, L1C(D+P) (GAL, QZS)	L6C	: E6C (GAL)
L1Z	: E1A+B+C (GAL)	L6X	: E6B+C (GAL)
L2C	: L2C/A (GPS, GLO)	L6Z	: E6A+B+C (GAL)
L2D	: L2 L1C/A-(P2-P1) (GPS)	L6S	: LEX-S (QZS) *
L2S	: L2C(M) (GPS, QZS)	L6L	: LEX-L (QZS) *
L2L	: L2C(L) (GPS, QZS)	L8I	: E5(a+b)I (GAL)
L2X	: L2C(M+L) (GPS, QZS)	L8Q	: E5(a+b)Q (GAL)
L2P	: L2P (GPS, GLO)	L8X	: E5(a+b)I+Q (GAL)
L2W	: L2 Z-track (GPS)		

\*: Extensions for QZSS

# Multi-GNSS Considerations in RTKLIB

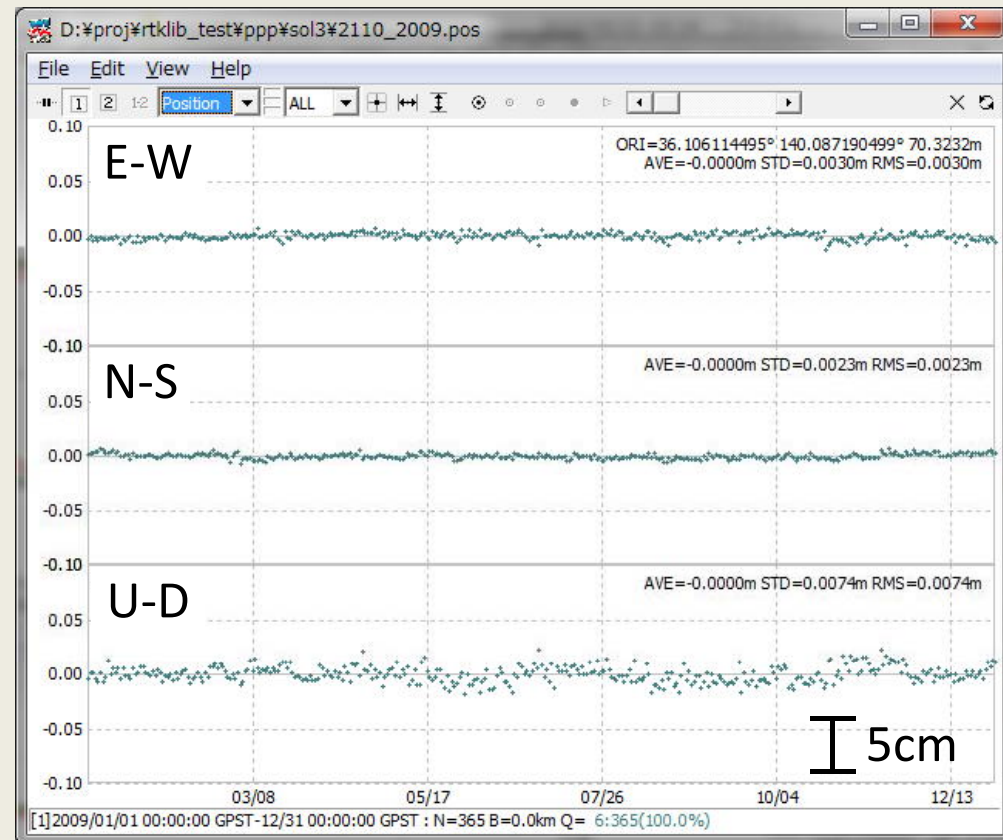
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- Time System
  - Internally handle time based on GPST
  - Estimate inter-system time offset for single/PPP mode
  - Need careful treatment for ephemeris computation
- Coordinate System
  - No need for explicit transformation based on ITRF
- Satellite/Receiver Dependent Bias
  - Incorporate of CODE DCB (P1-P2, P1-C1) for GPS
  - Estimate inter-channel bias for GLONASS-RTK
  - Need more experience for other GNSSs

# Static PPP with IGS Final

Geonet Station	Repeatability after Linear Fitting (mm)		
	E-W	N-S	U-D
0601	6.5	3.4	10.7
0837	4.4	2.9	10.8
0369	3.3	2.4	8.1
0579	3.1	2.2	8.6
0586	4.4	3.1	9.4
0241	3.3	2.3	8.4
0324	3.6	2.4	8.8
0174	3.7	2.7	8.9
3023	3.3	2.7	7.8
0905	3.7	2.8	8.1

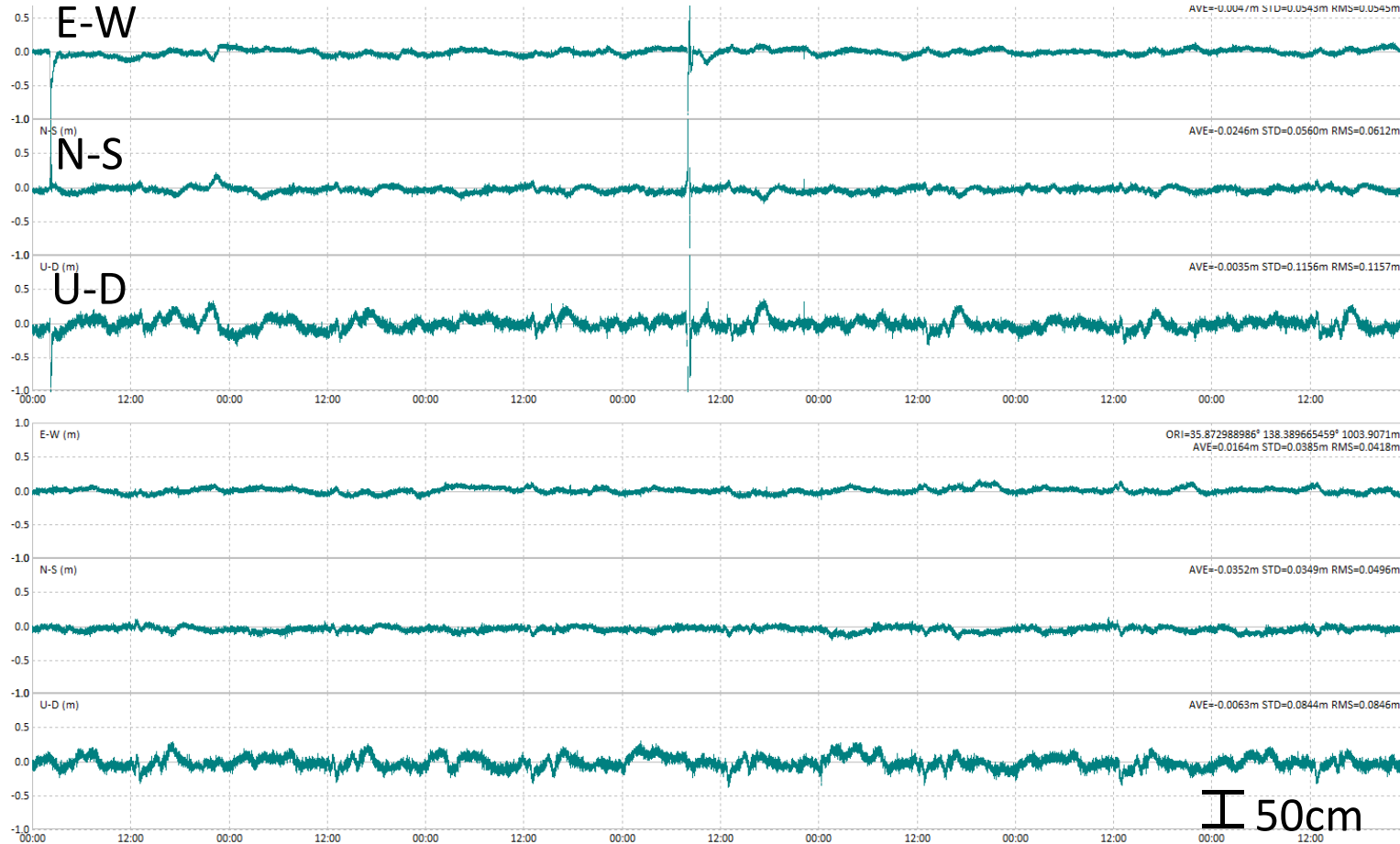
## GEONET2110: 2009/1/1-12/31



**STD E/N/U: 3.0 2.3 7.4 mm**

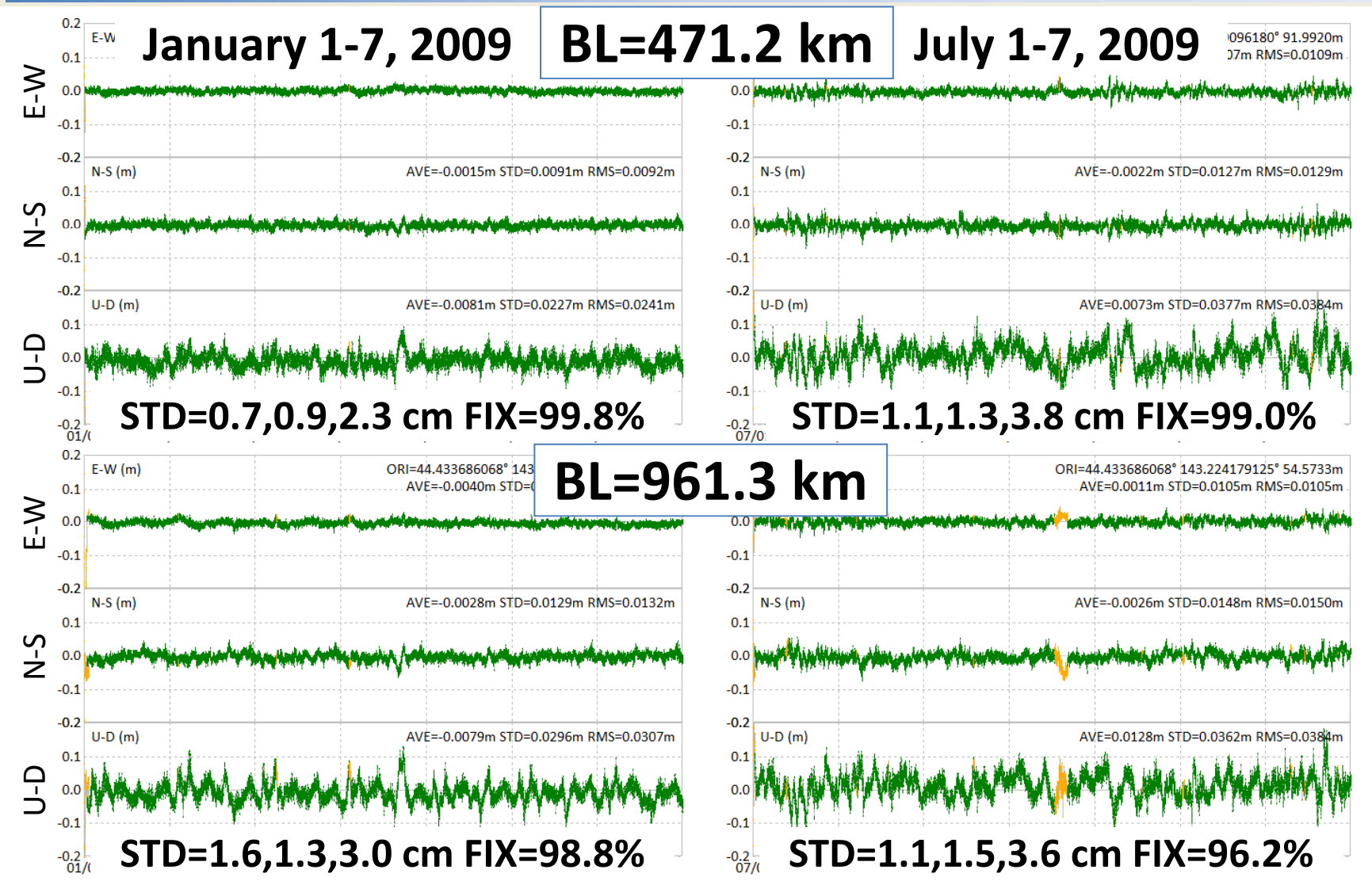
# Real-Time PPP with IGS Orbit/Clock

NovAtel, 2010/10/1 -10/14 1Hz with GSOC/DLR: CLK20



**RMS E/N/U: 4.9, 5.6, 10.1 cm**

# Long Baseline RTK



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# Future Plan



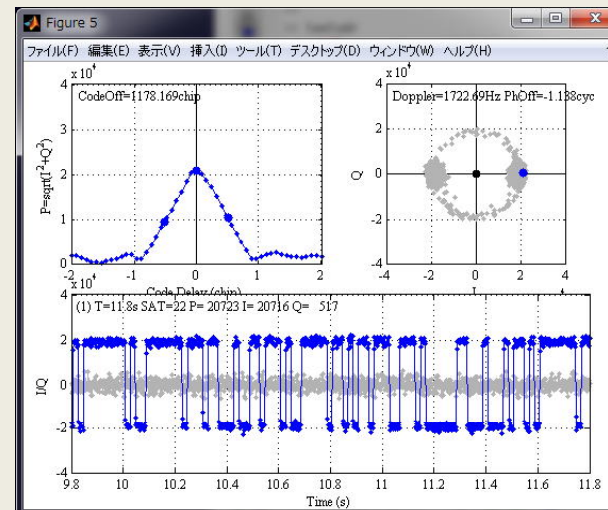
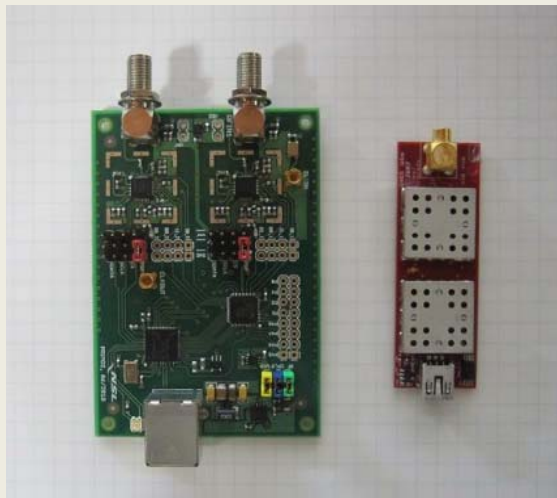
# Future Release

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- v. 2.4.1: End of 2010
  - Minor version-up to fix problems and bugs
- v. 2.5.0: Spring or Summer 2011
  - Restructure of internal data structure
  - Add formal support for QZSS (and Galileo)
  - Add single-frequency PPP
  - Improvement of PPP and Long-baseline RTK
  - Add several formats and receivers
  - S/W receiver module

# S/W Receiver for Multi-GNSS Signals

- SDR Receiver Module for RTKLIB
  - FFT-based parallel correlator for acquisition
  - S/W correlator for code/phase tracking
  - Navigation data decoder
- L1C/A, L1C for GPS/Galileo/QZSS and L1 GLONASS



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# Summary

# Summary

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- Introduction of Multi-GNSS
- Issues for Multi-GNSS Data Processing
  - Lack of standard format for newly coming GNSSs
  - Time/coordinate systems
  - Satellite/receiver dependent biases
- Multi-GNSS Implementation in RTKLIB
  - Features in latest version
  - Supported formats
  - Future release plan