GPS/GNSS Symposium 2010

QZSS LEXによるリアルタイムPPP実験とその拡張

Real-Time PPP Experiment via QZSS LEX and its Extension

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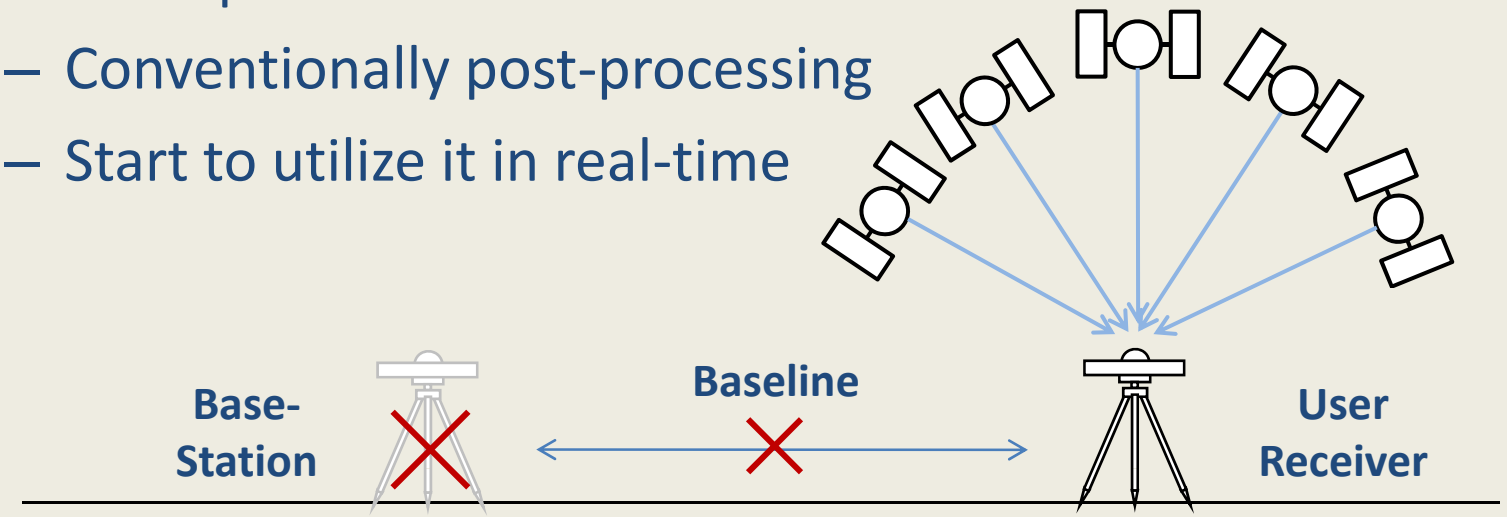
Outline

- What is PPP?
- Real-Time PPP Experiment via QZSS LEX
- Real-Time PPP Client Implementation
- Preliminary Performance Evaluation
- Future Extension of QZSS LEX PPP
- Summary

What is PPP?

PPP: Precise Point Positioning

- Carrier-Based Single Positioning with GNSS
  - Dm to mm-level accuracy
  - No need base-station and baseline
  - Global coverage world-wide
  - Need precise orbit and clock
  - Conventionally post-processing
  - Start to utilize it in real-time

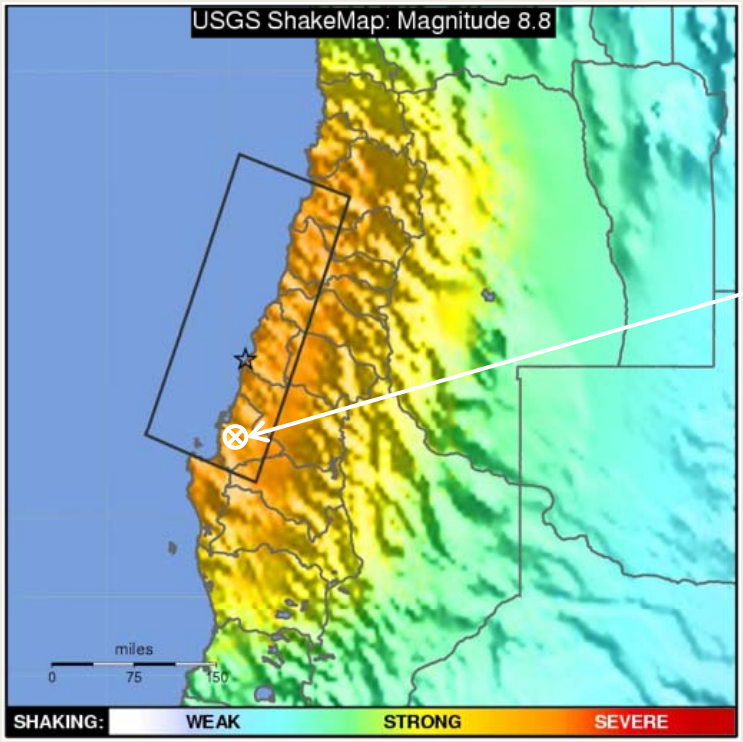


Comparison of RTK and RT-PPP

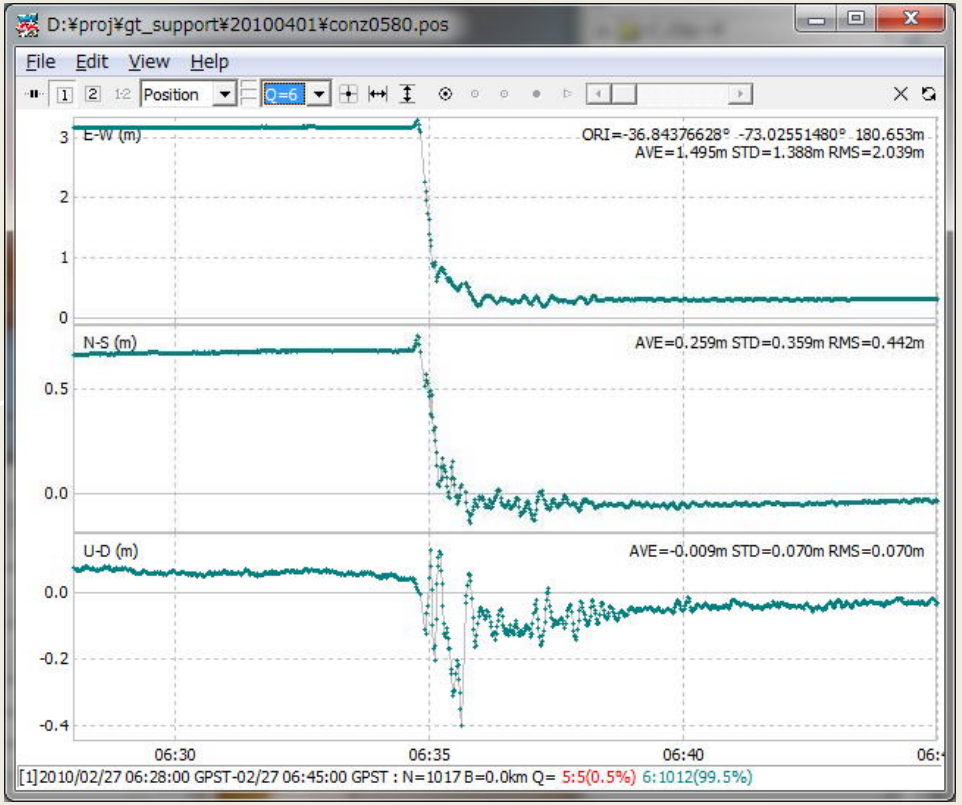
	RTK/Network-RTK	Real-Time PPP
Coverage	<100 km from Base	Global
Accuracy	2 cm HRMS	<10 cm HRMS
Convergence	< 30 s	30 min
Ionosphere	Eliminated by DD	Dual-Frequency
Ambiguity	Fixed	Float
Orbit/Clock	Broadcast	Precise
Communication	Point To Point	Satellite, Internet

Example of PPP AP (1/2)

2010/1/27 M8.8 Chilean Earthquake

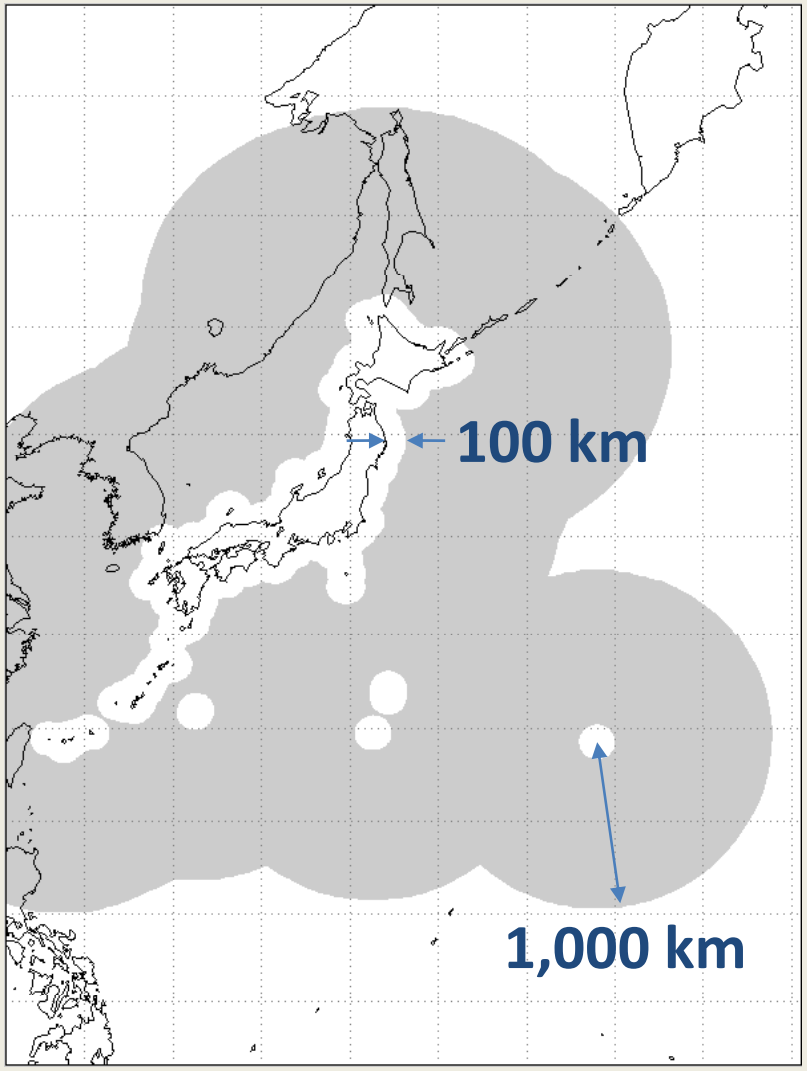


http://earthquake.usgs.gov/earthquakes



IGS CONZ, Orbit/Clock: CODE/CODE-5 s
2010/2/27 6:28-6:45 1 Hz, RTKPOST 2.4.0,
Mode: Kinematic PPP + Combined, GPS

Example of PPP AP (2/2)



GPS Tsunami Monitoring System (Currently ~20 km off-shore)

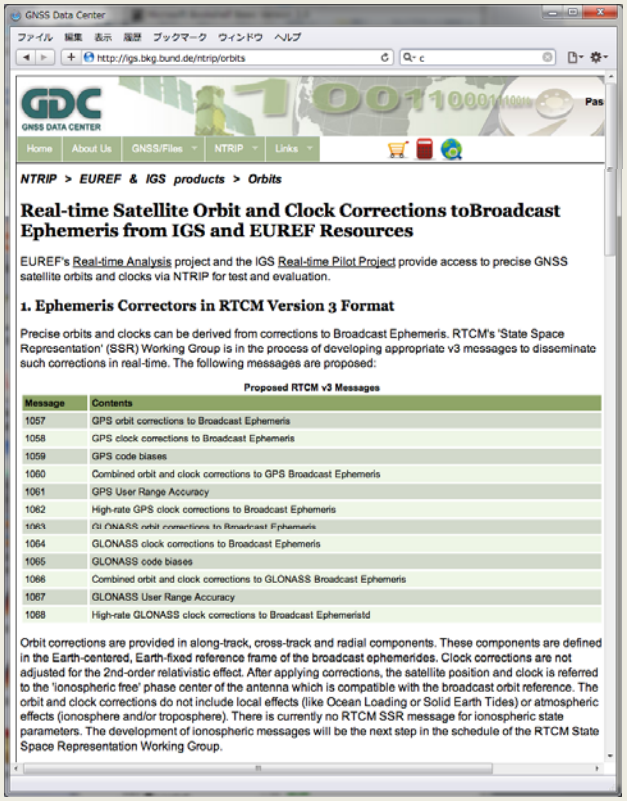
http://www.tsunamigps.com

Commercial RT-PPP Service

Provider	Service	Coverage	Broad-cast	Ref. Stations	Orbit/ Clock	Engine	Accuracy
NavCom	StarFire	World-wide	3 GEO L-band	60	1 min/ 1-2 s	JPL RTG	<10 cm H <15 cm V (1 sigma)
Fuguro	OmniSTAR XP/HP+	World-wide (Land)	6 GEO L-band	100	1 min/ 10 s	Fuguro	dm-class
	SeaSTAR XP/G2	World-wide (Sea)	6 GEO L-band	100	1 min/ 10 s	Fuguro/ ESOC (G2)	dm-class
VERIPOS	VERIPOS Ultra/Apex	World-wide	7 GEO L-band	80	30 s/ 30 s	JPL/ ESOC	10 cm H 20 cm V (95%)

IGS RT Orbit/Clock

- Developed by IGS RTPP
  - Corrections to broadcast ephemeris
  - RTCM v.3 MT1057-1068 (SSR)
  - NTRIP stream via Internet
  - Interval: 10 s, Latency: 5 - 10 s
  - Free of charge
- Provided by several ACs
  - Orbit: fixed to IGU or estimated
  - Clock: estimated with IGS real-time tracking network



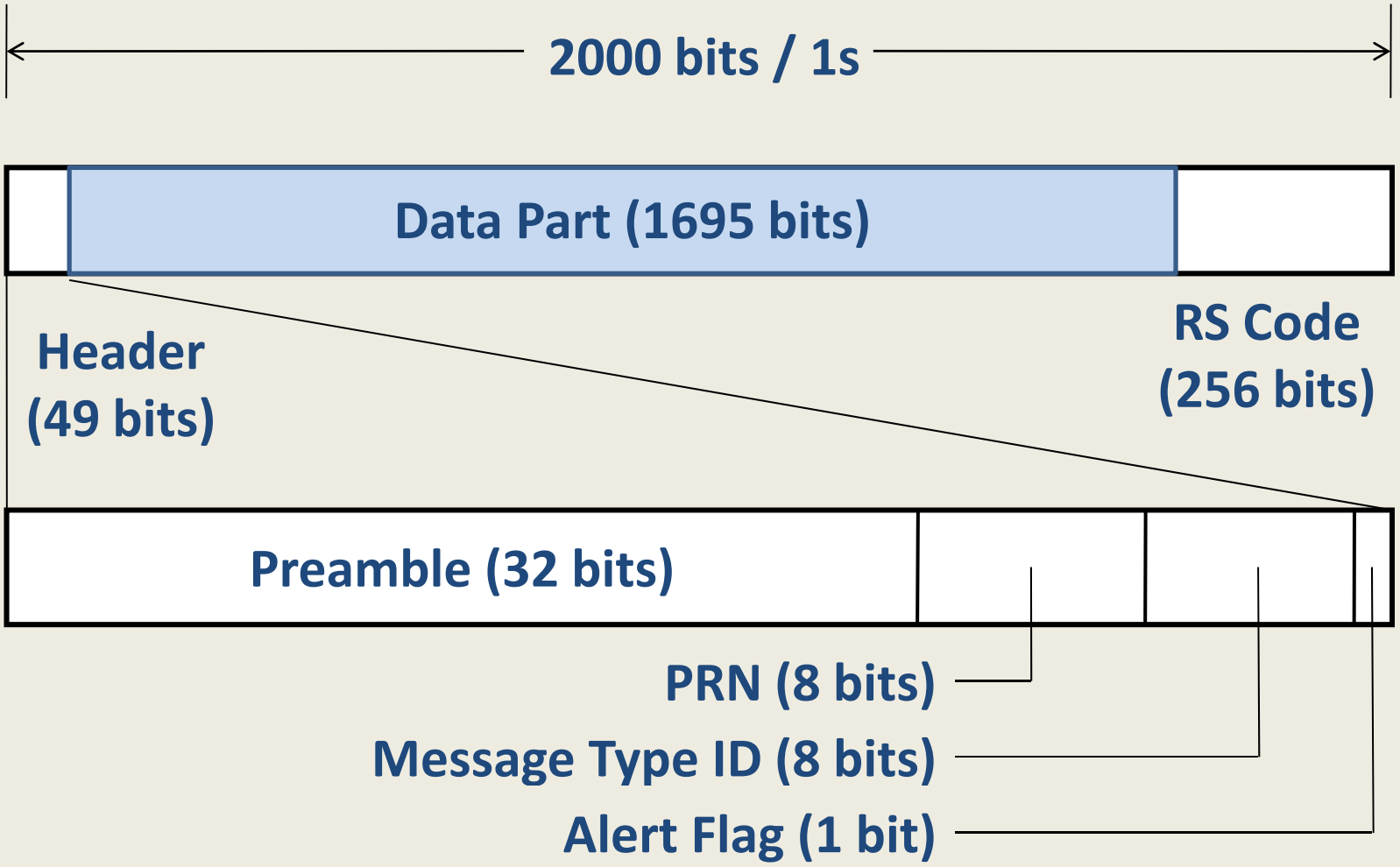
http://igs.bkg.bund.de

Real-Time PPP Experiment via QZSS LEX

QZSS LEX Signal

		Specification
Frequency		1278.75MHz (= Galileo E6 CS)
Bandwidth		42.0MHz
Signal Power		-155.7dBW (Min)
Modulation		BPSK (5) , Short-Kasami-Sequence
Spreading Code	Short	Period: 4ms, Length: 10,230 chips
	Long	Period: 410ms, Length: 1,048,575 chips
Navigation Data		2000 bits/frame, 1 frame/s

QZSS LEX Message



QZSS LEX Message Type ID

MT		Contents
0-9		Reserved
10-19		JAXA Experiment
	10	Signal Health (35 Satellites) Ephemeris and SV Clock (3 Satellites)
	11	Signal Health (35 Satellites) Ephemeris and SV Clock (2 Satellites) Ionosphere Correction
	12-19	Reserved
20		GSI Experiment
21-255		Other Experiment

JAXA Experiment (1/2)

- Signal Health
  - 32 GPS + 3 QZSS, L1, L2, L5, L1C, LEX
- Ephemeris and SV Clock
  - 32 GPS + 3 QZSS satellites
  - 3nd order coefficients of ECEF position and URA
  - Clock bias/drift and DCB
- Ionosphere Correction
  - 2nd/1st order coefficients of vertical delay
  - Regional coverage near Japan

JAXA Experiment (2/2)

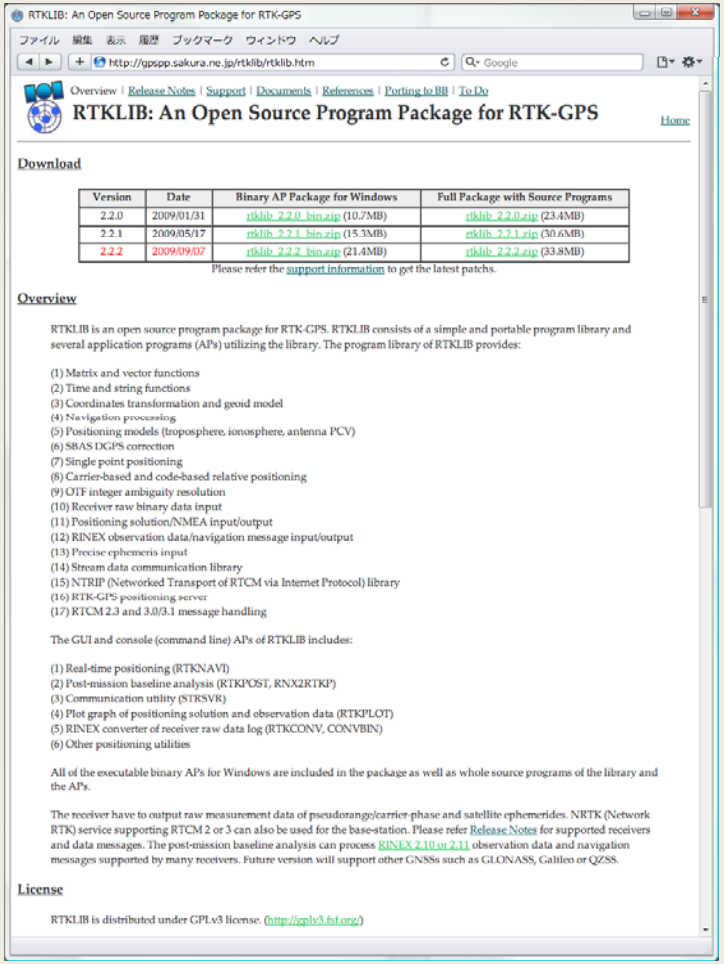
Message Interval (Nominal)

Message	Broadcast	Update	Effective Period
Signal Health	1 s	1 s	-
Ephemeris	12 s	3 min	6 min
SV Clock	12 s	3 min	6 min
Ionosphere	12 s	30 min	-

Real-Time PPP Client Implementation

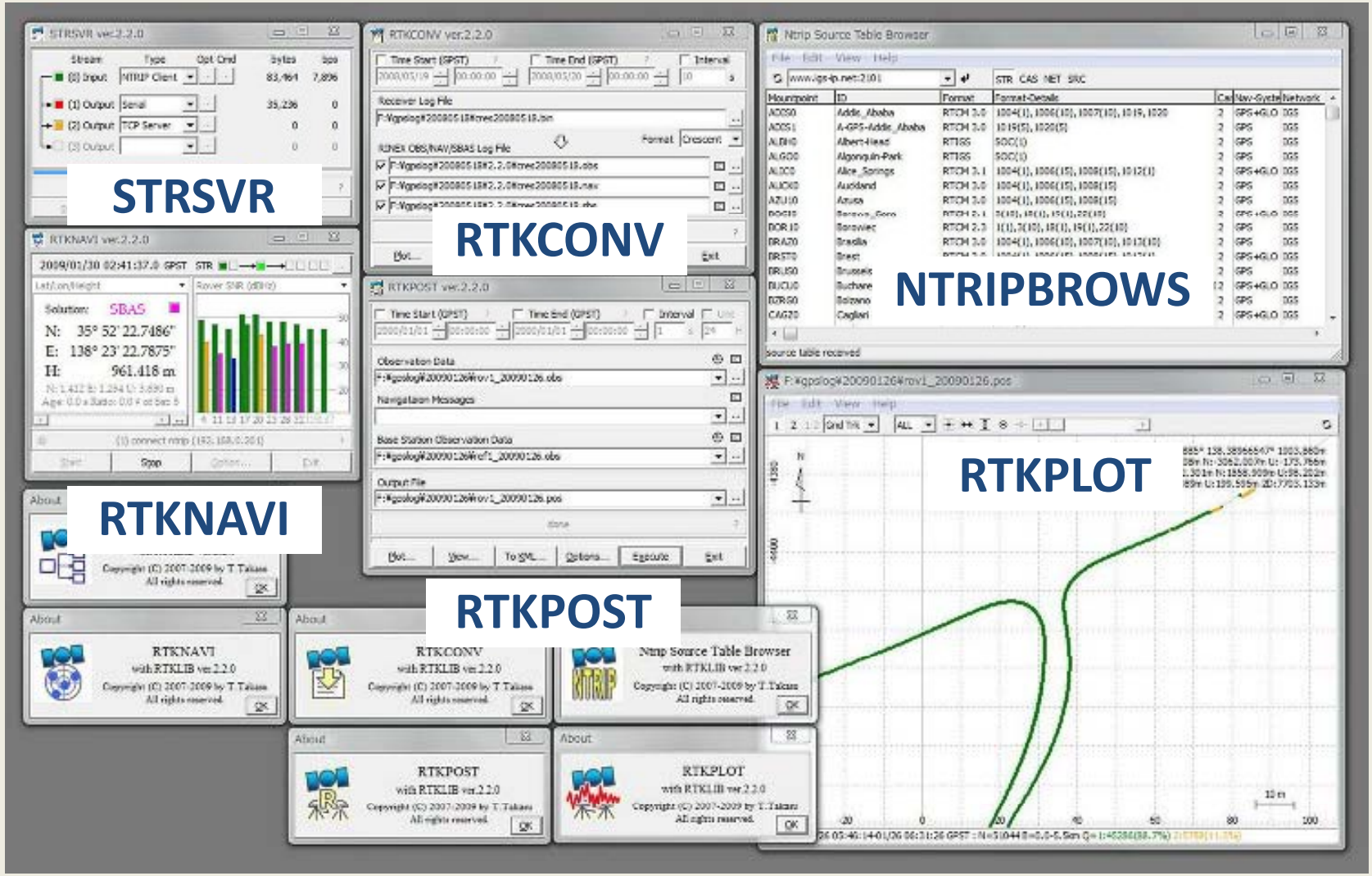
RTKLIB

- 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



http://www.rtklib.com

RTKLIB APs



RTKLIB Features

- 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 2.2, RINEX 3.0, 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

- 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

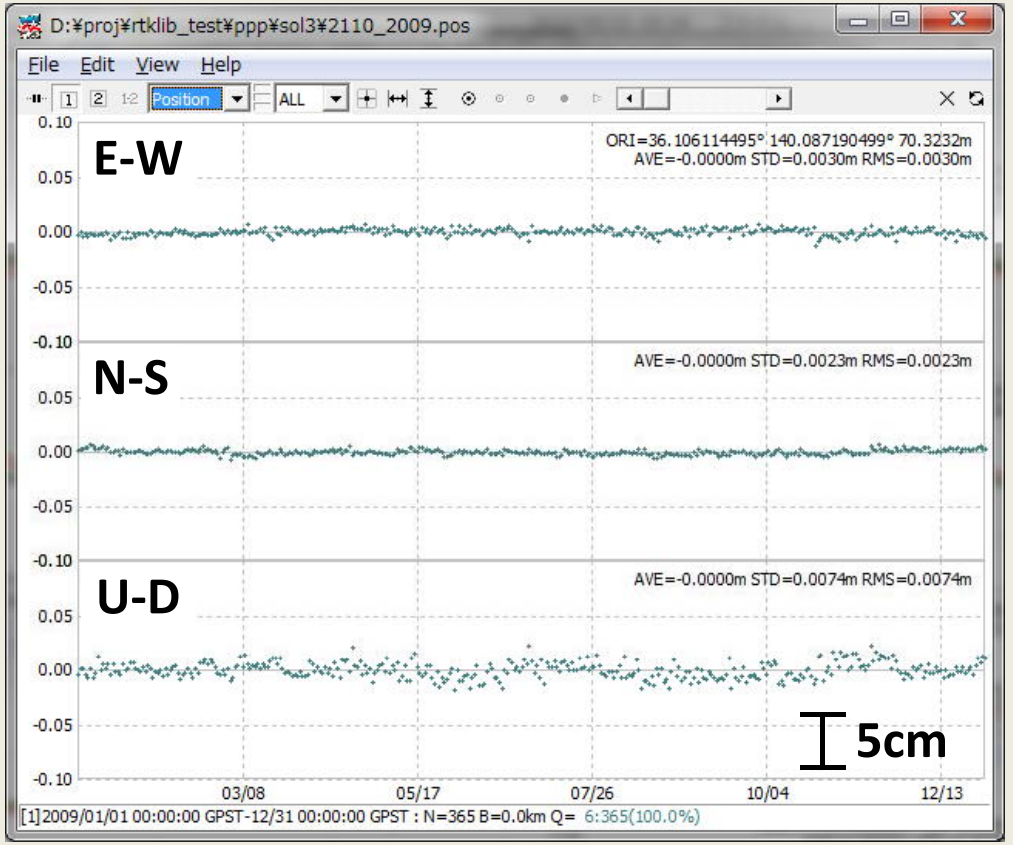
PPP Features in RTKLIB 2.4.0

- Kalman-Filter Based Parameter Estimator
  - PPP-Kinematic or PPP-Static mode
- Atmosphere Corrections:
  - Only L3-LC with dual-frequency for Ionosphere
  - ZTD and gradient estimation with NMF
- Sold Earth Tide Model by IERS 2003 (subset)
- Satellite and Receiver Antenna PCV models
  - ANTEX (IGS05.ATX) or NGS
- Antenna Wind-up Correction for Phase

Static 24H 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

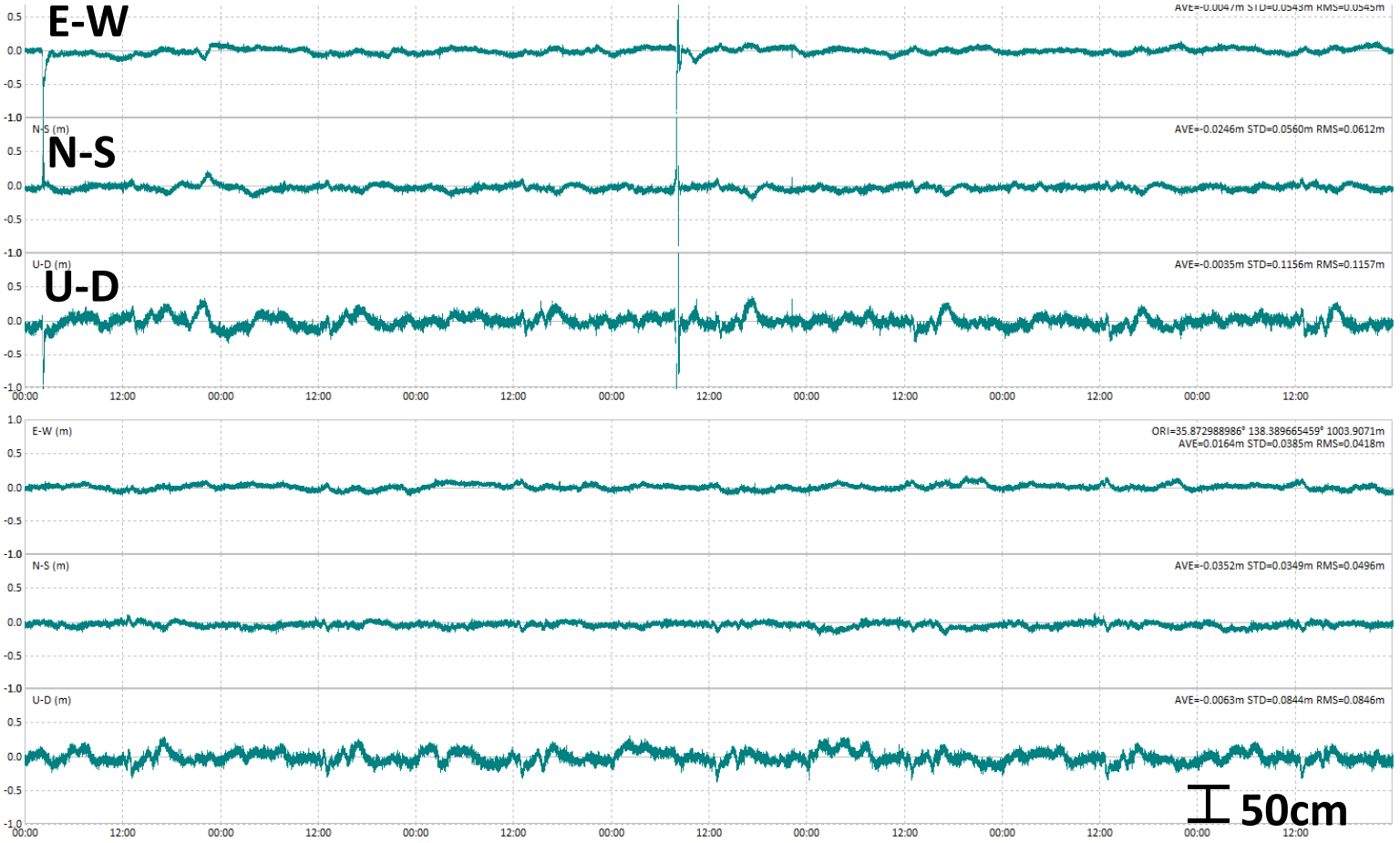
GEONET2110: 2009/1/1-12/31



STD E/N/U: 3.0 2.3 7.4 mm

RT-PPP with IGS RT Orbit/Clock

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



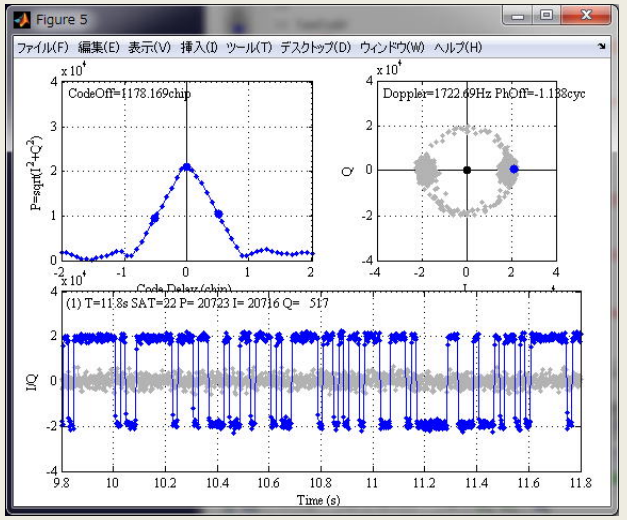
RMS E/N/U: 4.9, 5.6, 10.1 cm

QZSS Extension for RTKLIB

- Support for QZSS satellites
  - Single, DGPS, RTK and PPP with QZSS
  - RINEX 2.2, RINEX 3.0, SP3, ANTEX and RTCM for QZSS
- Support for LEX MT 10 and 11
  - LEX message handling
  - Ephemeris and SV clock model
  - Ionosphere correction model
  - Single-Frequency PPP
- Support for LEX receiver proprietary message
- Utility for post-processing

Future Plan of RTKLIB

- v. 2.4.1: End of 2010
  - Fix problems and bugs
- v. 2.5.0: Spring or Summer 2011
  - SDR front end for GPS/GLONASS/QZSS (L1)
  - Support of Galileo/QZSS
  - Single-Frequency PPP
  - Improvement of PPP
  - Add supported formats
  - ...



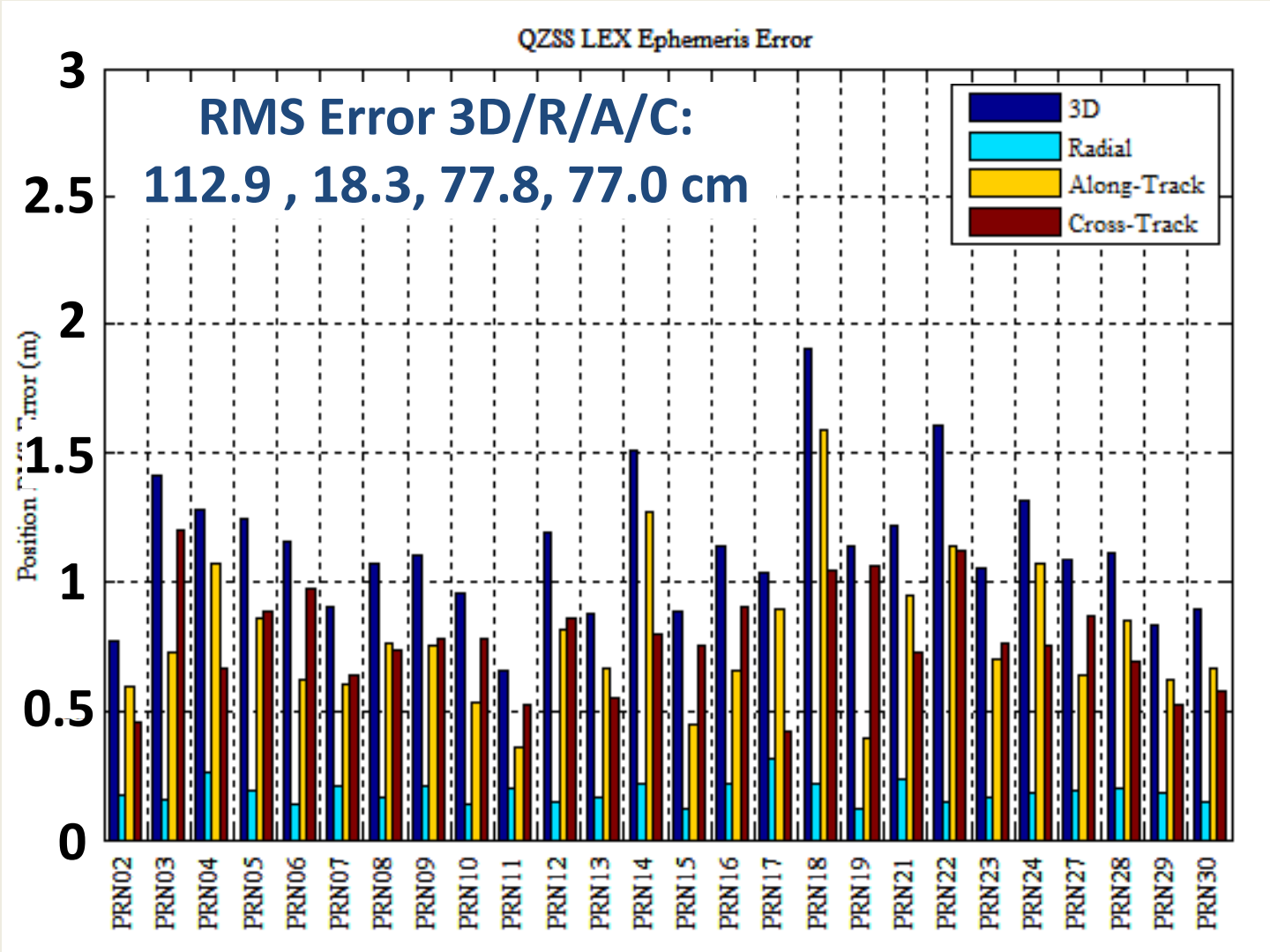
SDR prototype for RTKLIB 2.5.0

Preliminary Performance Evaluation

Preliminary Evaluation

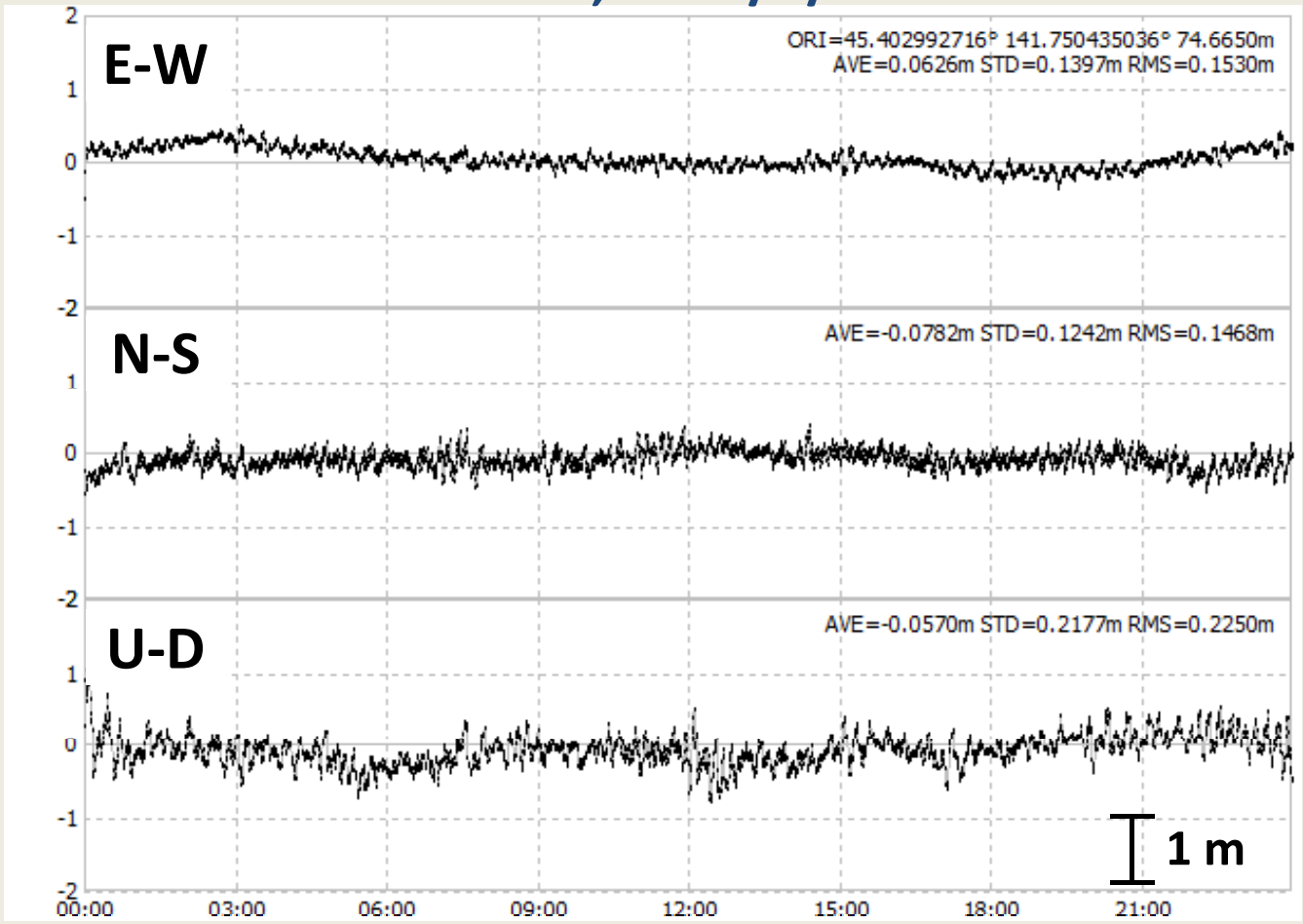
- LEX Data for JAXA Experiment
  - 2010/08/03 0:00:00-23:59:59 24H
  - Generated in ground system Integration test
  - LEX MT 10, 11 only corrections for GPS
  - 13 Monitor Stations
- Post-processing PPP Test
  - RTKPOST 2.4.0 + LEX extension
  - 4 GEONET stations 30 s x 24 H
- Positioning Mode
  - Kinematic PPP with L1/L2 and L1 only

LEX GPS Orbit Accuracy



Kinematic PPP with LEX Correction

GEONET 0001 Wakkanai, 2010/8/3 0:00:00-23:59:30



RMS E/N/U: 15.2, 14.2, 21.6 cm

LEX Experiment Plan

- January - March 2011
- Evaluation of LEX PPP Performance
  - Dual-freq/Single-freq PPP
  - Convergence Time of PPP
  - Stationary and moving receiver
- Evaluation of LEX Orbit and Clock
  - GPS orbit and clock
  - QZSS orbit and clock
- Evaluation of LEX Ionospheric Correction

Future Extension of QZSS LEX PPP

Future LEX PPP

- Real-time PPP with multi-GNSS
  - Real-time orbit and clock for all GNSS available
  - Uniform time and coordinate among different GNSS
- PPP-AR (ambiguity resolution)
  - Satellite-side carrier-phase bias correction
  - Need more precise orbit and clock (< 3 cm)
- Regional precise atmospheric corrections
  - STEC instead of VTEC for ionosphere
  - ZTD/MF or 3D NWM for troposphere
- Bandwidth Limitation vs. Target User/AP

Summary

Summary

- What is PPP?
  - Applications
  - Real-Time PPP
- RT PPP Experiment via QZSS LEX
- RT PPP Client Implementation with RTKLIB
- Preliminary Evaluation Result
- Future Enhancement of LEX PPP