International Symposium on GPS/GNSS 2010

Development of Real-Time PPP Client for Precise Satellite Orbit and Clock Corrections via NTRIP

Tokyo University of Marine Science and Technology

Tomoji TAKASU

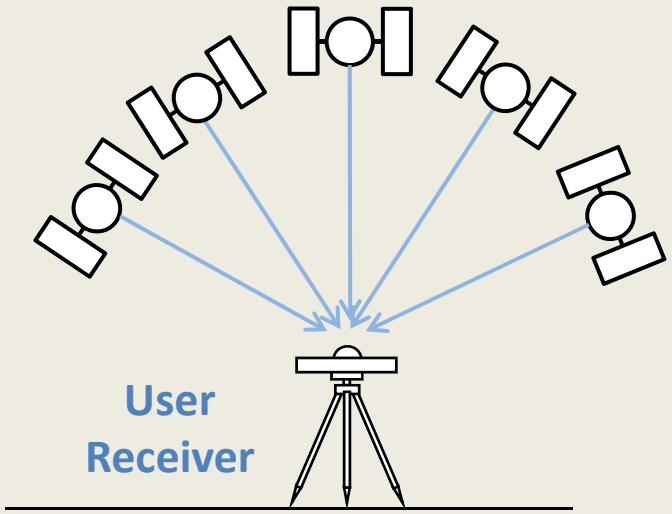
Outline

- Background
- Real-Time Precise Orbit and Clock
- Real-Time PPP Client Implementation
- Performance Evaluation
- Future Plan
- Conclusion

Background

PPP: Precise Point Positioning

- Carrier-Based Single Positioning with GNSS
  - Sub-dm - cm-level accuracy by post processing
  - Need precise orbit and clock
  - Need dual-frequency for ionosphere elimination
  - Long TTFF due to float ambiguity (> 30 min)
  - Global coverage world-wide
- Applications
  - Crustal deformation monitoring
  - GPS meteorology
  - POD of LEO satellite



Real-Time PPP

- Demand for RT PPP Application
  - Users who can not find nearby reference station
  - Out of coverage of Network-RTK service
  - Marine AP or AP on vast ground
  - Continuous monitoring of natural hazard like Tsunami
- Commercial RT PPP Services via Satellite Links
  - NavCom : StarFire™
  - Fuguro : OmniStar XP/HP+, SeaStar XP/G2
  - VERIPOS : VERIPOS Ultra/Apex
  - Need dedicated receiver and service charge

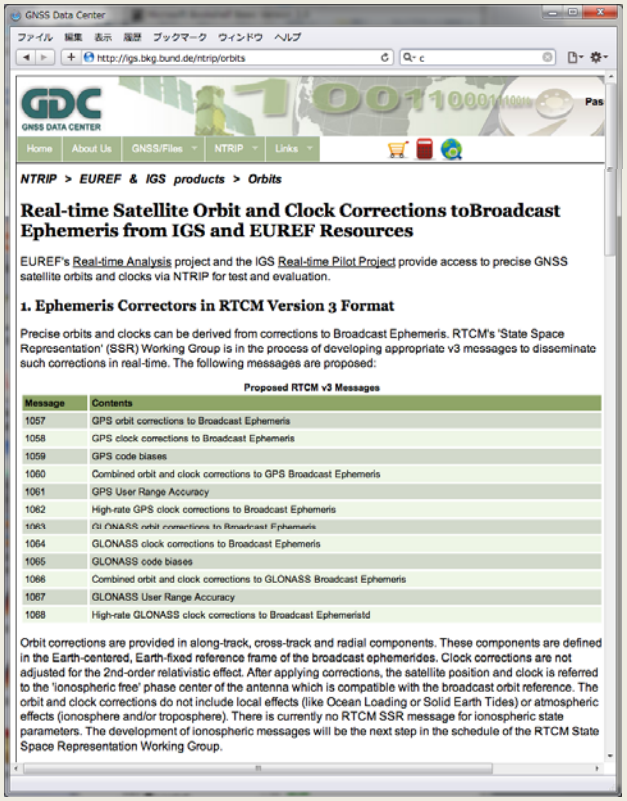
Real-Time PPP Issues

- Lack of RT Precise Orbit and Clock
  - Poor clock accuracy of IGU: ~ 3ns (~ 1 m)
  - Proprietary messages by commercial RT PPP service
  - Complicated RT processing to produce orbit and clock
  - Need open and standard RT orbit and clock easily available
- Lack of Receiver or S/W Supporting RT PPP
  - Most of PPP S/W only support post-processing
  - Only few dedicated receivers support RT PPP with commercial RT PPP service
  - Need open and flexible S/W for RT PPP

Real-Time Precise Orbit and Clock

IGS RT Orbit/Clock

- Developed by IGS RTPP
  - RTCM v.3 MT1057-1068 (SSR)
  - Corrections to broadcast ephemeris
  - Real-time NTRIP stream via Internet
  - Interval: 10 s, Latency: 5 - 15 s
  - Currently free of charge
- Several ACs
  - Orbit: fixed to IGU or estimated
  - Clock: estimated with IGS real-time tracking network



http://igs.bkg.bund.de

RTCM v.3 SSR Messages

MT	Contents
1057	GPS Orbit Corrections
1058	GPS Clock Corrections
1059	GPS Code Biases
1060	GPS Combined Orbit and Clock Corrections
1061	GPS URA
1062	High-Rate GPS Clock Corrections
1063	GLONASS Orbit Corrections
1064	GLONASS Clock Corrections
1065	GLONASS Code Biases
1066	GLONASS Combined Orbit and Clock Corrections
1067	GLONASS URA
1068	High-Rate GLONASS Clock Corrections

IGS RT Orbit/Clock Distribution

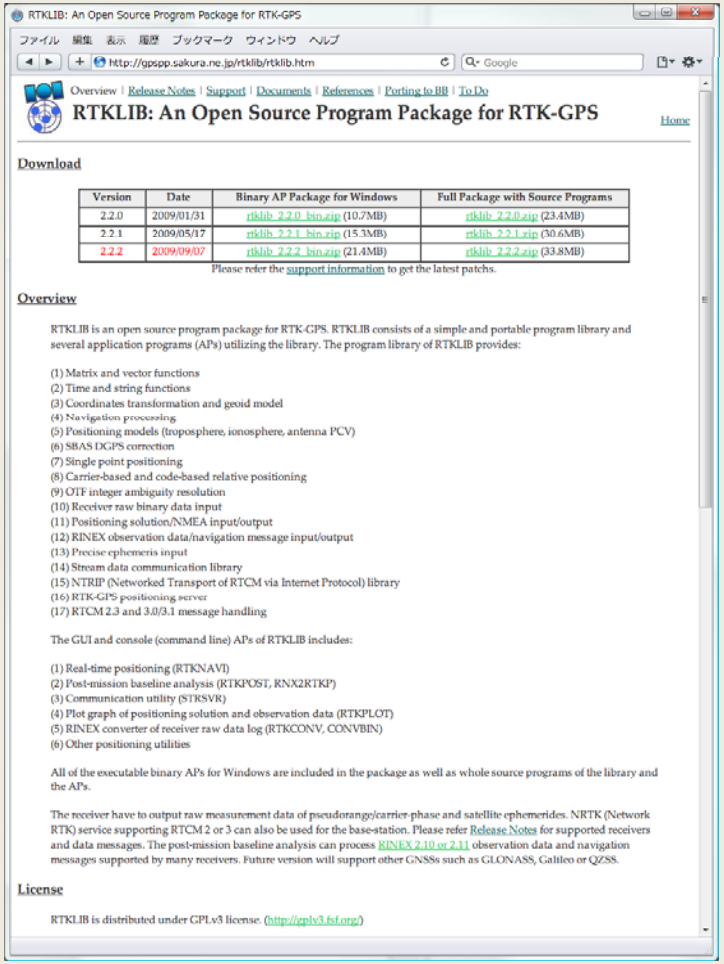
AC	Mount Point	GNSS	RTCM MT	Orbit	Analysis S/W
BKG	CLK00, CLK10 *1	GPS	1059, 1060	IGU	RTNet + BNS
	CLK01, CLK11, CLK41-45 *1	GPS, GLO	1059, 1060 1065,1066	IGU	
GSOC/DLR	CLK20 *1	GPS	1059, 1060	IGU	RETICLE
	CLKA1, CLKC1 *2	GPS	1059, 1060	IGU	
ESA/ESOC	CLK30, CLK31 *1	GPS	1059, 1060	IGU	COMBI+BNS
	CLK50-53 *1	GPS	1059, 1060	IGU	RETINA+BNS
TUW	CLK61 *1	GPS	1059, 1060	IGU	RTIGSMR+BNS
GFZ	CLK70, CLK71 *1	GPS	1059, 1060	IGU	Epos-RT+BNS
GMV	CLK80, CLK81 *1 GMVAPC, GMVCOM *3	GPS	1059, 1060	IGU	magicGNSS+ BNS
Geo++	RTCMSSR, RTCMSSR1060 *4	GPS, GLO	1057-1060, 1060-1066	Dynamic	GNSMART

*1: products.igs-ip.net, *2: gnss.gsoc.dlr.de, *3: igs-ip.gmv.com, *4: wox.geopp.de

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 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

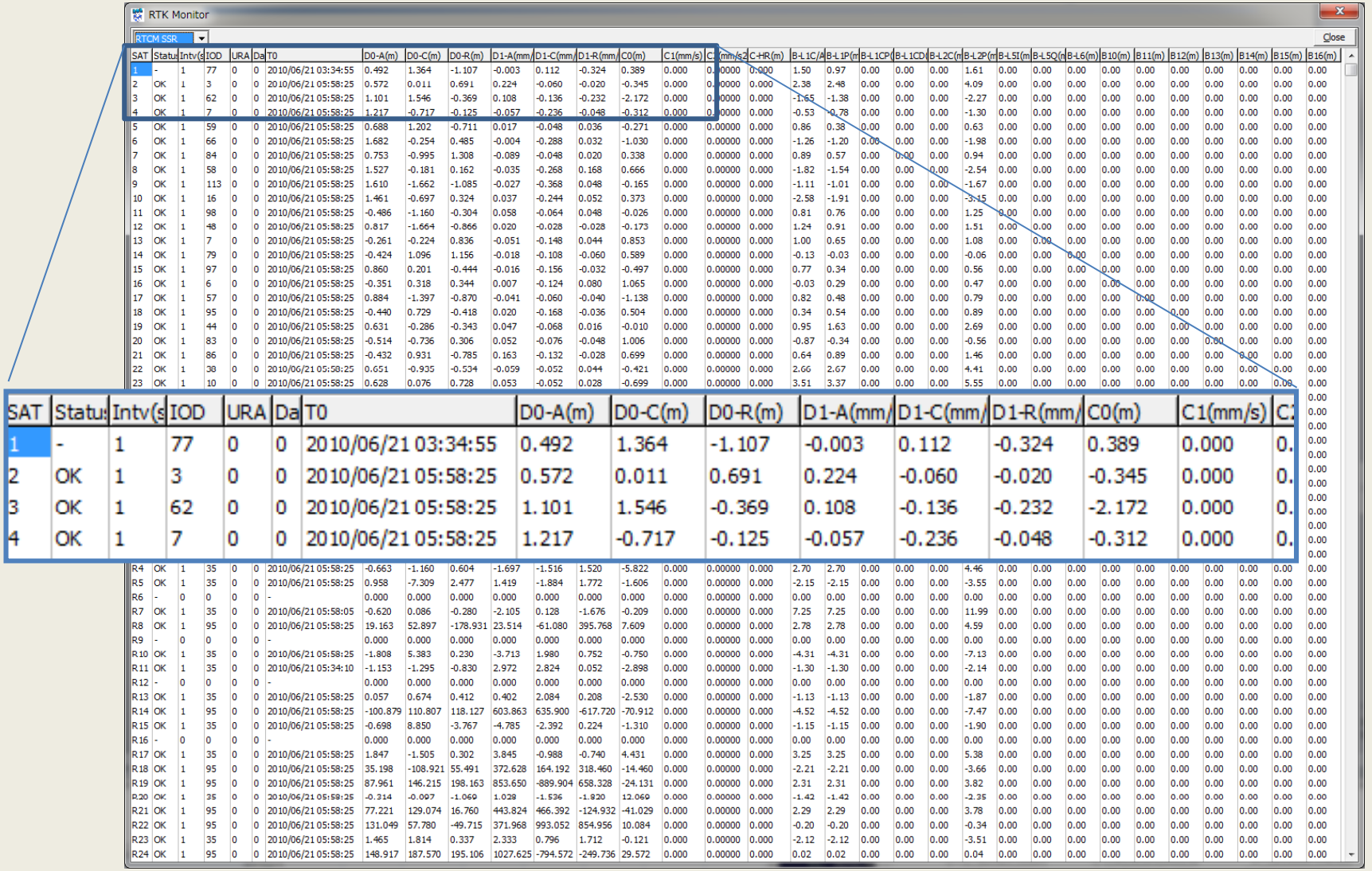
RTKLIB 2.4.0

- 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

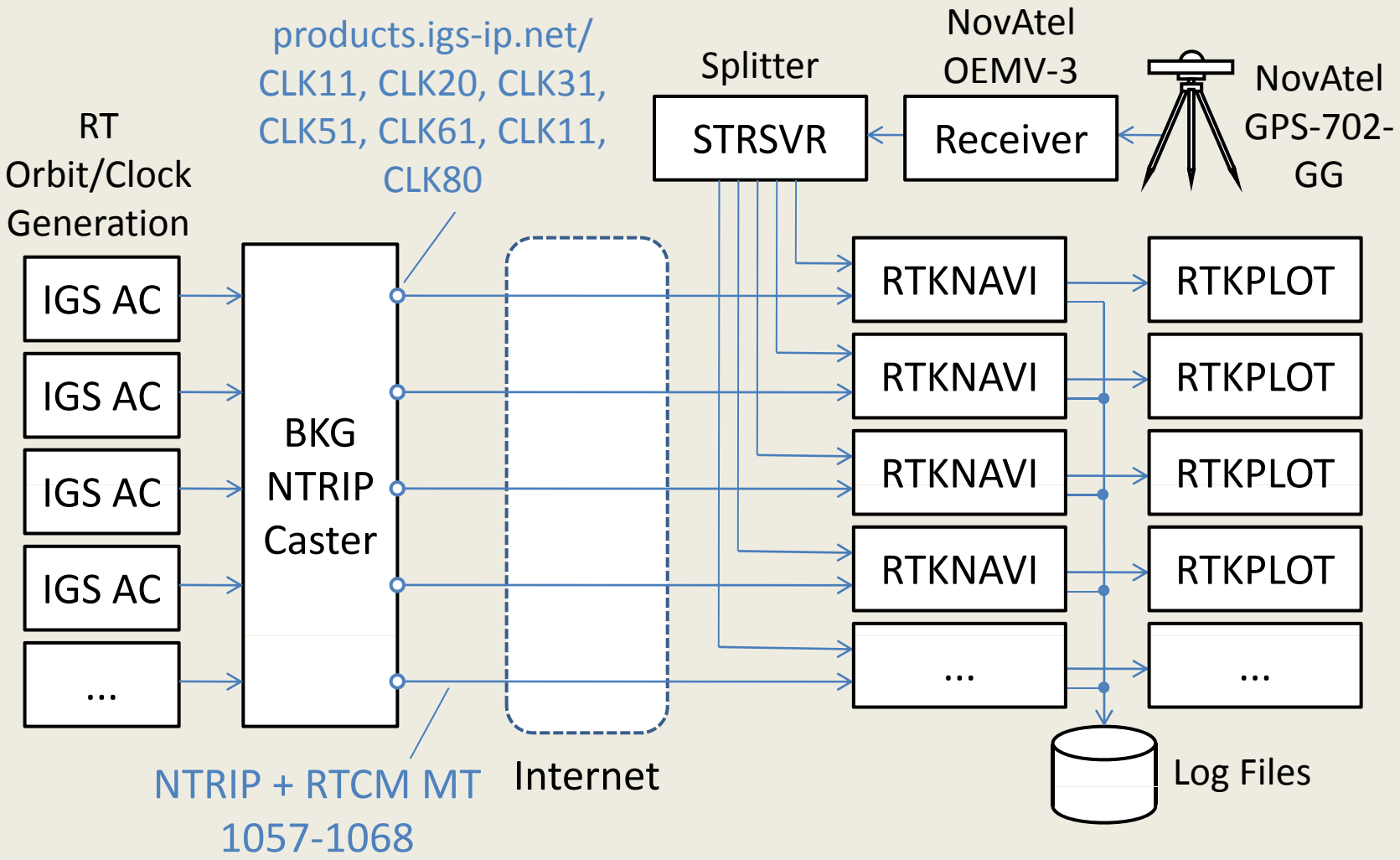
Example of RT Orbit/Clock



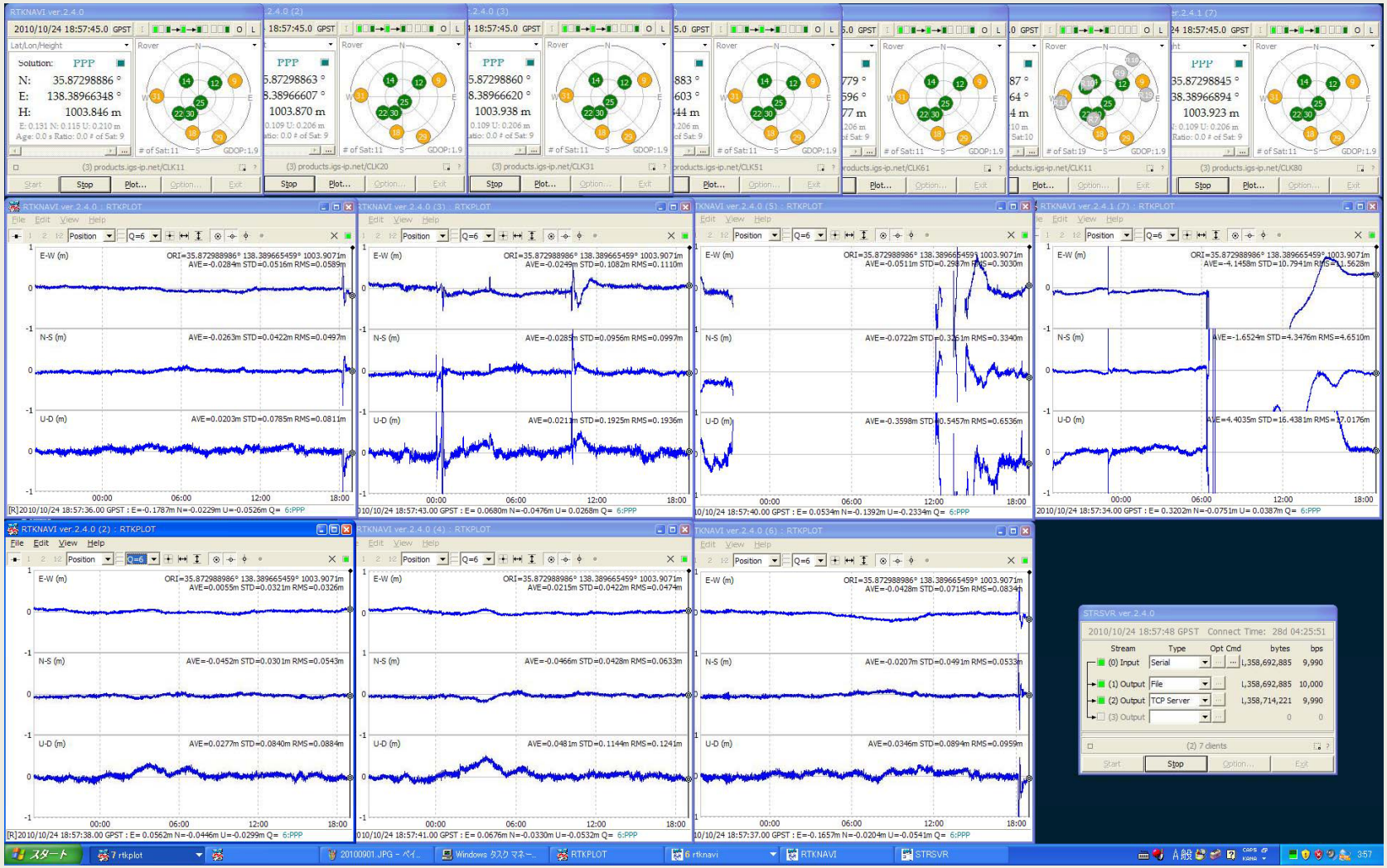
SAT	Status	Intv(s	IOD	URA	Da	T0	D0-A(m)	D0-C(m)	D0-R(m)	D1-A(mm/	D1-C(mm/	D1-R(mm/	C0(m)	C1(mm/s)	C
1	-	1	77	0	0	2010/06/21 03:34:55	0.492	1.364	-1.107	-0.003	0.112	-0.324	0.389	0.000	0.
2	OK	1	3	0	0	2010/06/21 05:58:25	0.572	0.011	0.691	0.224	-0.060	-0.020	-0.345	0.000	0.
3	OK	1	62	0	0	2010/06/21 05:58:25	1.101	1.546	-0.369	0.108	-0.136	-0.232	-2.172	0.000	0.
4	OK	1	7	0	0	2010/06/21 05:58:25	1.217	-0.717	-0.125	-0.057	-0.236	-0.048	-0.312	0.000	0.

Performance Evaluation

Setup of Experiment

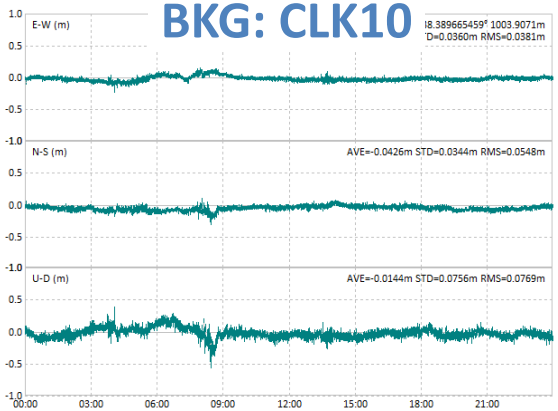


Snapshot of Experiment



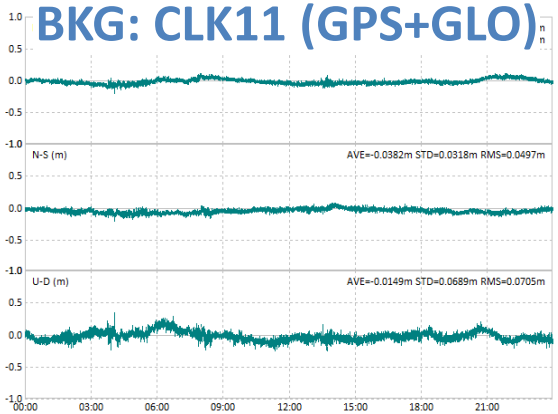
PPP-Kinematic Result (24H)

BKG: CLK10



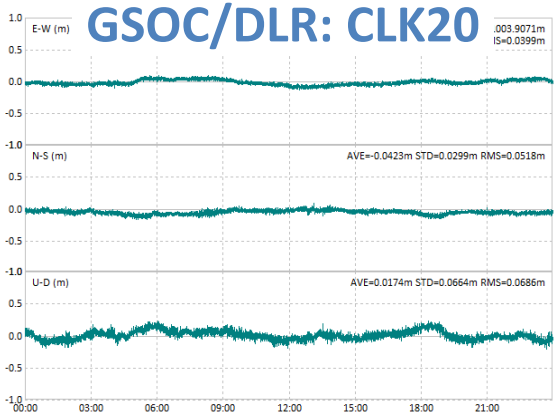
RMS: 3.8, 5.5, 7.7cm

BKG: CLK11 (GPS+GLO)



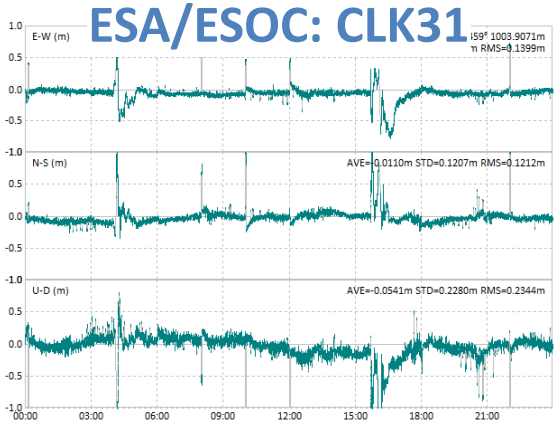
RMS: 3.8, 5.0, 7.1cm

GSOC/DLR: CLK20



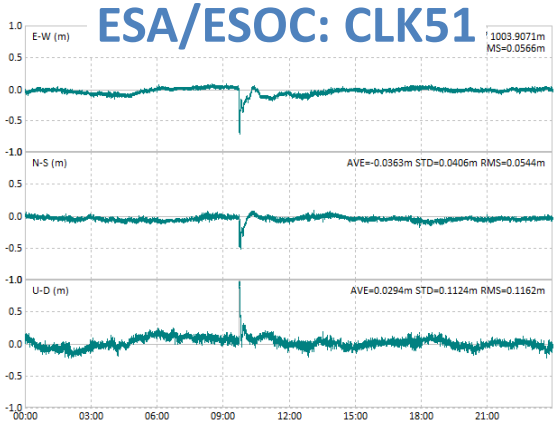
RMS: 4.0, 5.2, 6.9cm

ESA/ESOC: CLK31



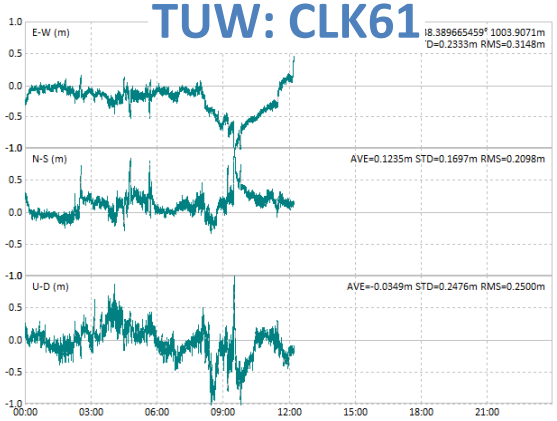
RMS: 14.0, 12.1, 23.4cm

ESA/ESOC: CLK51



RMS: 5.7, 5.4, 11.6cm

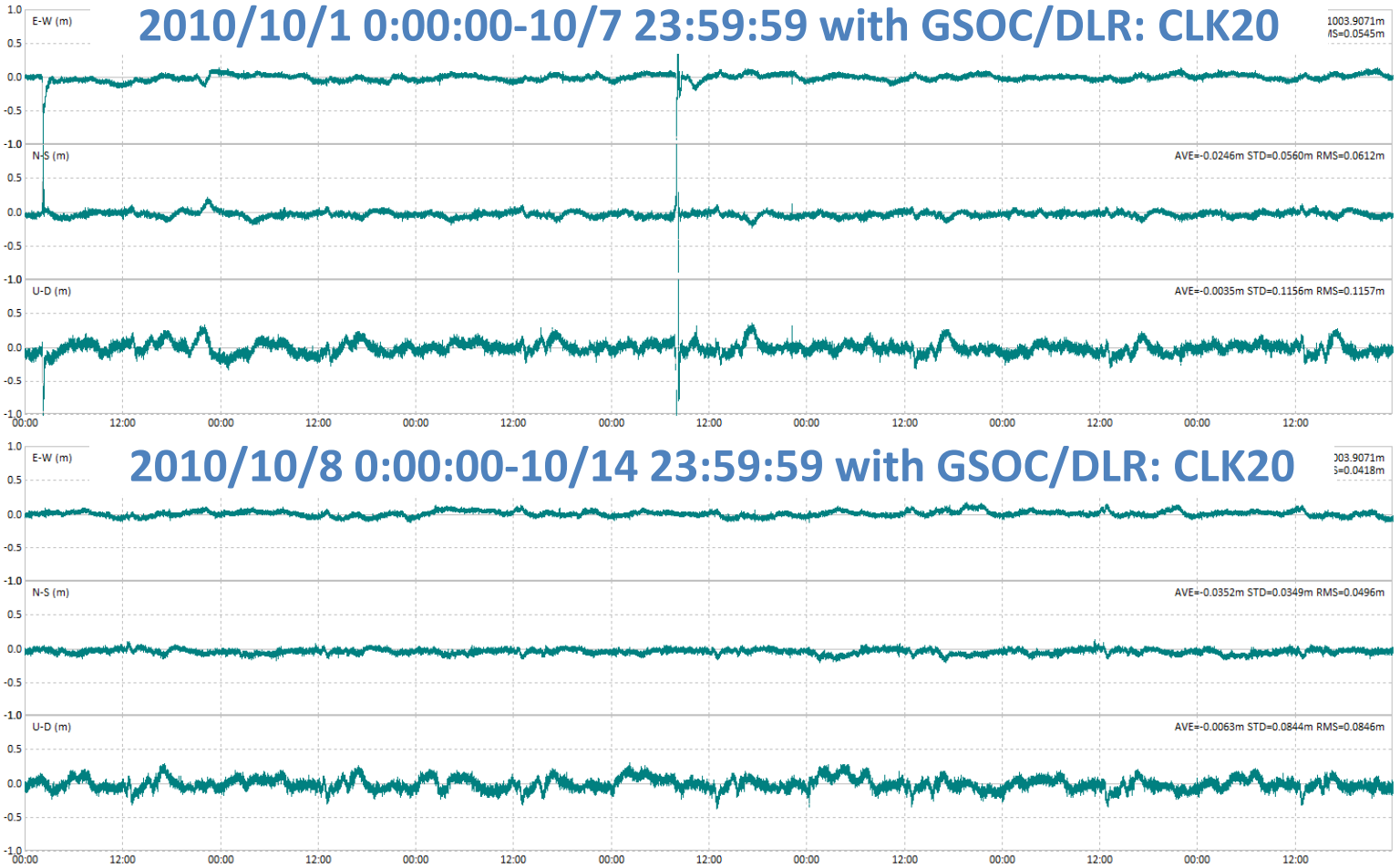
TUW: CLK61



RMS: 23.3, 21.0, 25.0cm

2010/9/18 0:00-23:59, 1Hz, NovAtel OEMV-3+GPS-702, RTKLIB 2.4.0

PPP-Kinematic Results (2 weeks)



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

Future Plan

Future Enhancement

- Single Frequency RT-PPP
  - With IGS predicted IONEX with automatic download
  - Ionosphere eliminated by using (L1+P1)/2 LC
  - Future support of ionosphere SSR for by IGS-RTPP
- PPP-AR (ambiguity resolution)
  - Need server-side support by network analysis
  - Future support of PPP-AR by IGS-RTPP
- Multi-GNSS RT-PPP
  - Also need server-side support for RT orbits/clocks of Galileo, QZSS, Compass, ...

Conclusion

Conclusion

- Real-Time PPP Issues
  - Lack of precise RT Orbit and Clock
  - Lack of receiver or S/W supporting RT PPP
- Real-Time Orbit and Clock provided by IGS-RTPP
- Real-Time PPP Implementation in RTKLIB v.2.4.0
- dm-level accuracy by PPP-Kinematic Mode
- Future Enhancement

IGS RT-Orbit/Clock: **http://igs.bkg.bund.de**
RTKLIB 2.4.0: **http://www.rtklib.com**