Comparitive Analysis of Online Static GNSS Post-Processing Services

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Oregon State University

Project Introduction

Introduction

- OPUS-Static
  - Popular in US
  - User submits single, static GPS observation
- Limitations
  - GPS-only
  - Files decimated to 30 sec logging rate
- Other services available
  - AUSPOS – Geoscience Australia
  - CSRS-PPP – Natural Resources Canada
  - GAPS – University of New Brunswick
  - TrimbleRTX – Trimble, Inc.
  - And more

Objectives

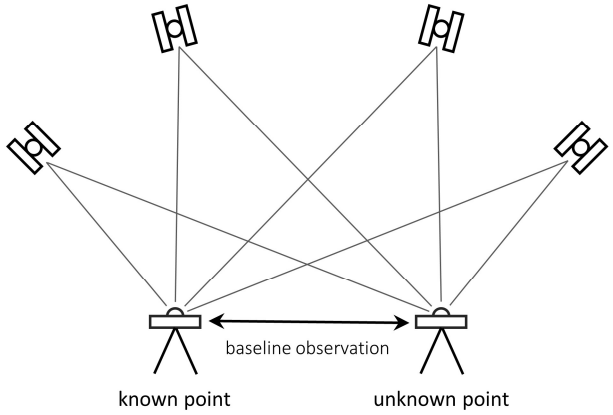
1. Compare accuracy of online static GNSS post-processing services
   Submit identical data files

2. Investigate accuracy using increased logging rate and addition of GLONASS
   Submit 6 variations of data files:
   10, 15, 30 second logging rates, each with GPS-only and GPS+GLONASS

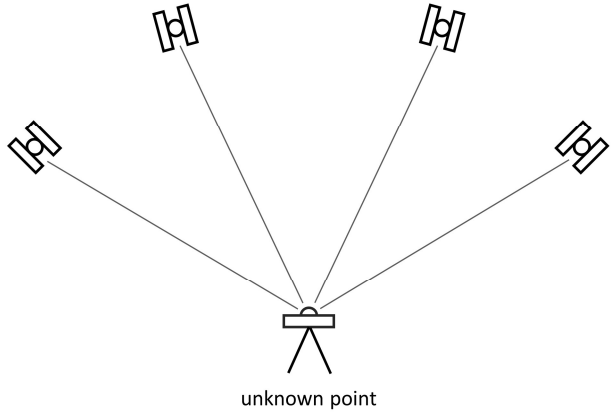
Background on Post-Processing Services

Relative Positioning vs Precise Point Positioning

- Relative Positioning
  - Use differencing to remove errors
  - Dependant on active stations
  - Believed to be more accurate



- Precise Point Positioning (PPP)
  - Only mathematical models to remove errors
  - No active stations needed
  - Relies on precise satellite ephemerides



Summary of Post-Processing Services

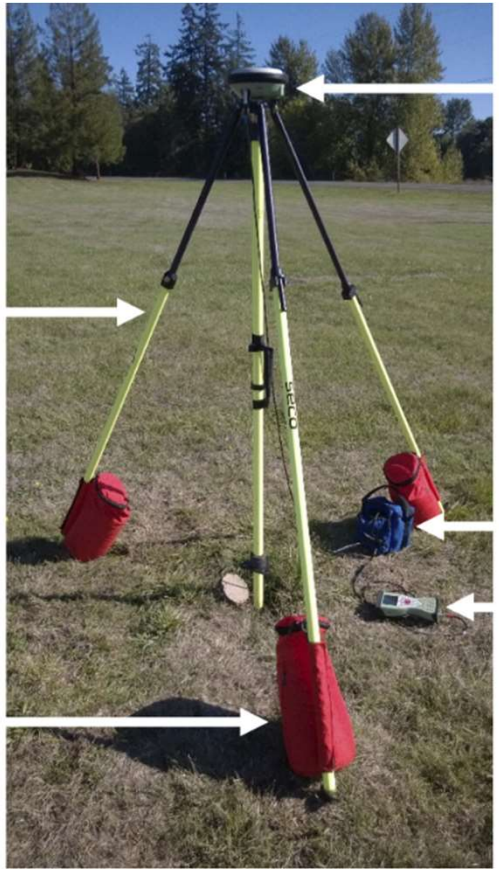
Service Name	Positioning Technique	Satellites	Minimum Duration (Recommended)	Process Rate	Orbit Source	Solution Format
OPUS-S	Relative	GPS only	2 hours (4 hours)	30 sec	IGS	Email, XML
AUSPOS	Relative	GPS only	1 hour (6 hours)	30 sec	IGS	PDF, SINEX
CSRS-PPP	PPP	GPS, GLONASS	None (>2 hours)	Down to 1 sec*	IGS and NRCan	PDF, CSV, SUM, POS
GAPS	PPP	GPS, Galileo, BeiDou	None (2 to 3 hours)	30 sec	IGS and NRCan	HTML, JPG, KML, etc.
TrimbleRTX	PPP	GPS, GLONASS, QZSS, BeiDou	10 min (>1 hour)	Down to 10 sec	Trimble	PDF, XML

*During batch processing, CSRS-PPP decimated our data files that were more than 4 hours in duration to a logging rate of 30 seconds. However, CSRS-PPP processed our data at a 1 second logging rate if they were uploaded individually.

Methodology

Data Source

- 2014 height mod survey
  - 18 marks
  - 10+ hour observations
  - 1 second epoch
  - GPS and GLONASS
- “True” coordinates
  - OPUS-Projects + ADJUST
  - Uncertainty at 95% confidence
    - 0.4 – 0.5 cm horizontally
    - 1.1 – 1.3 cm vertically
- Chosen for analysis
  - 6 marks
    - 3 minimal multipathing potential
    - 3 moderate multipathing potential



Gillins, D. and Eddy, M. (2016)

Setups

Moderate Obstruction

B726 - North

GLAS - East

LBCC - East

Minimal Obstruction

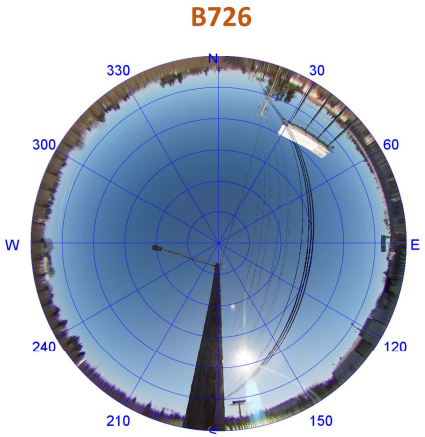
BICK - North

Y683 - North

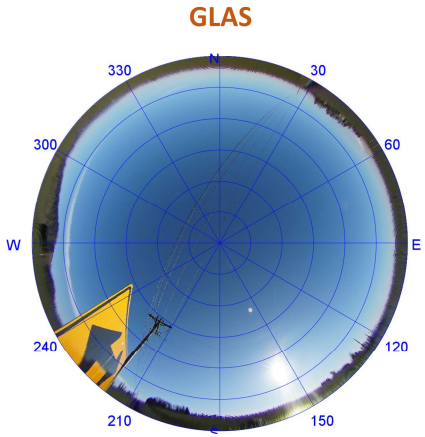
U727 - West

Skyplots

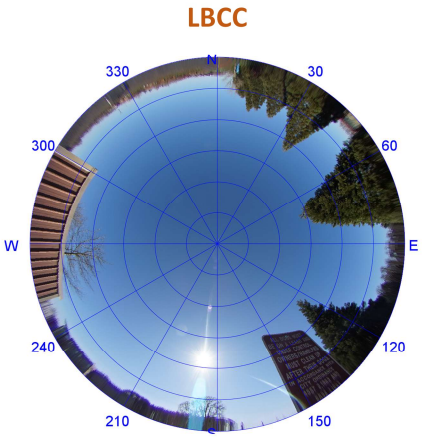
Moderate Obstruction



B726

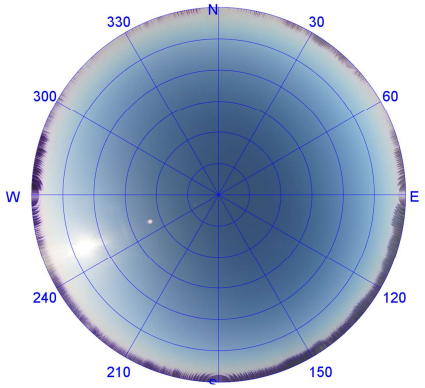


GLAS

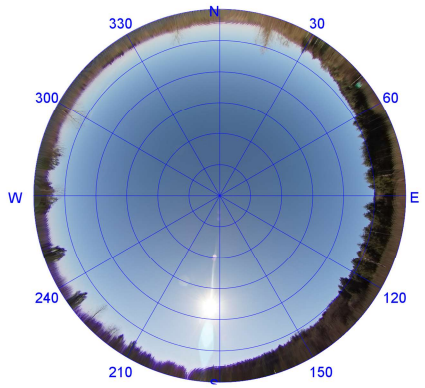


LBCC

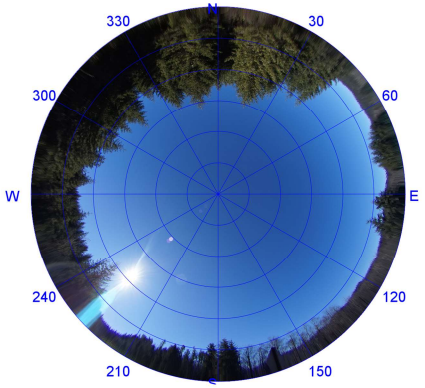
Minimal Obstruction



BICK

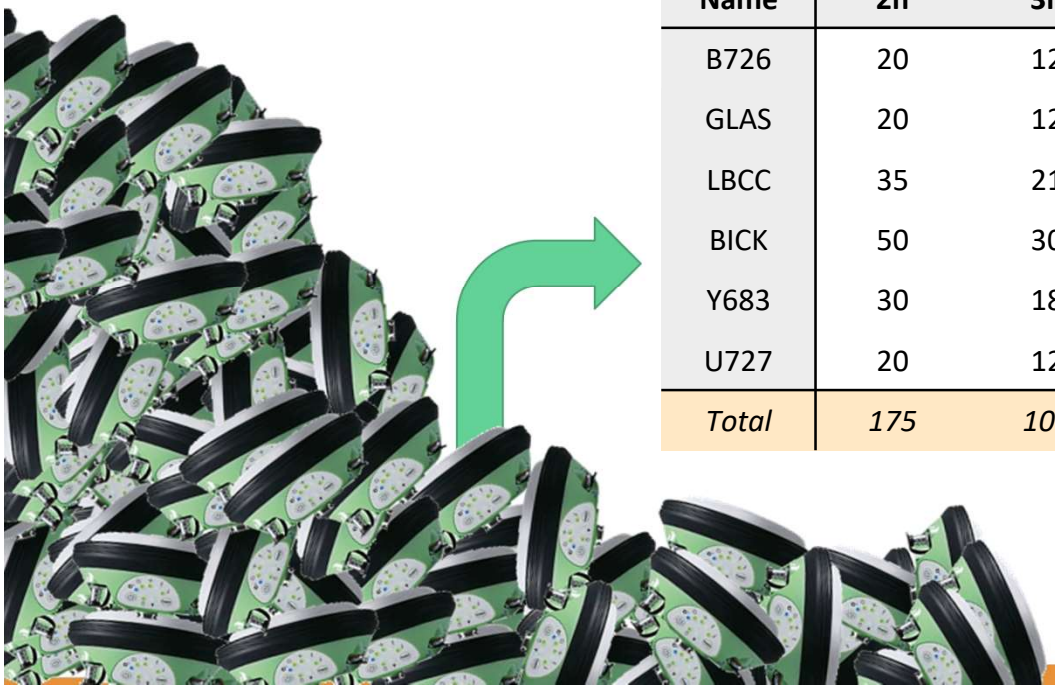


Y683



U727

Windowed Data and Sample Sizes



Number of windowed files on each mark, organized by observation duration

Mark Name	Duration of Observation 2h	3h	4h	5h	7h	10h	*Total*
B726	20	12	8	8	4	4	*56*
GLAS	20	12	8	8	4	4	*56*
LBCC	35	21	14	14	7	7	*98*
BICK	50	30	20	20	10	10	*140*
Y683	30	18	12	12	6	6	*84*
U727	20	12	8	8	4	4	*56*
Total	*175*	*105*	*70*	*70*	*35*	*35*	***490***

Figure Credit to Nick Forfinski

Results

Evaluating the Results

- Computed HRMS and VRMS for each sample on each mark

$$HRMS = \sqrt{\frac{\Sigma(\Delta n^2 + \Delta e^2)}{n}}$$

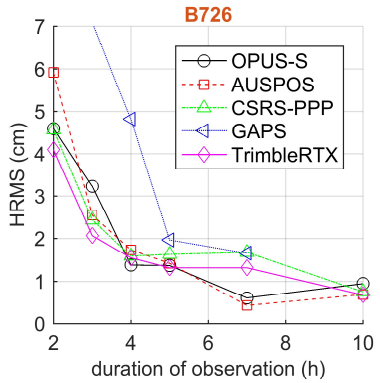
$$VRMS = \sqrt{\frac{\Sigma(\Delta u^2)}{n}}$$

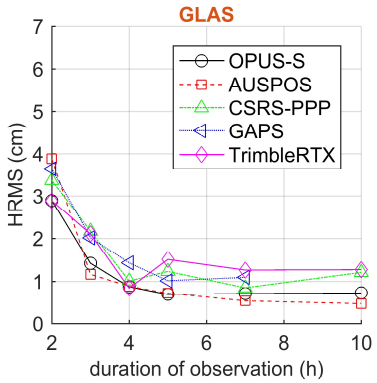
Objective 1

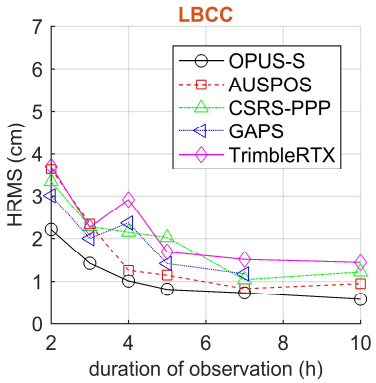
- Compare services using identical submissions
  - 5 services: OPUS-S, AUSPOS, CSRS-PPP, GAPS, TrimbleRTX
- General takeaway:
  - Relative positioning and PPP can perform similarly
  - Services converge at 4+ hours
- Problems
  - AUSPOS – two 10 hr solutions with huge residuals
  - GAPS – files cropped at GPS midnight. No 10 hour session solutions available. Unusually large RMS on B726.

Post-Processing Services Results - HRMS

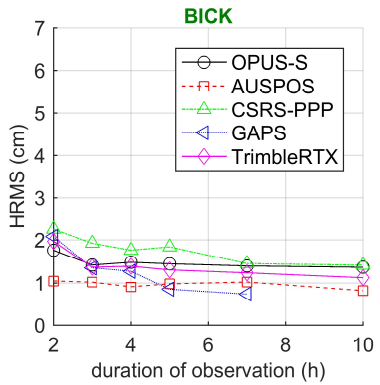
Moderate Obstruction

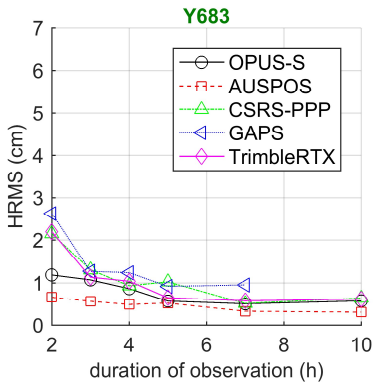


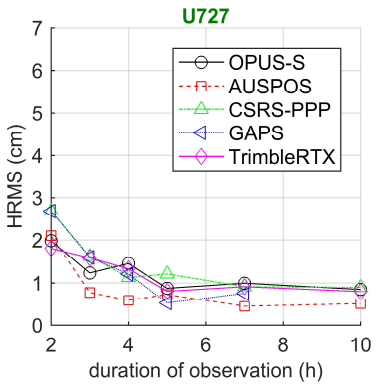




Minimal Obstruction



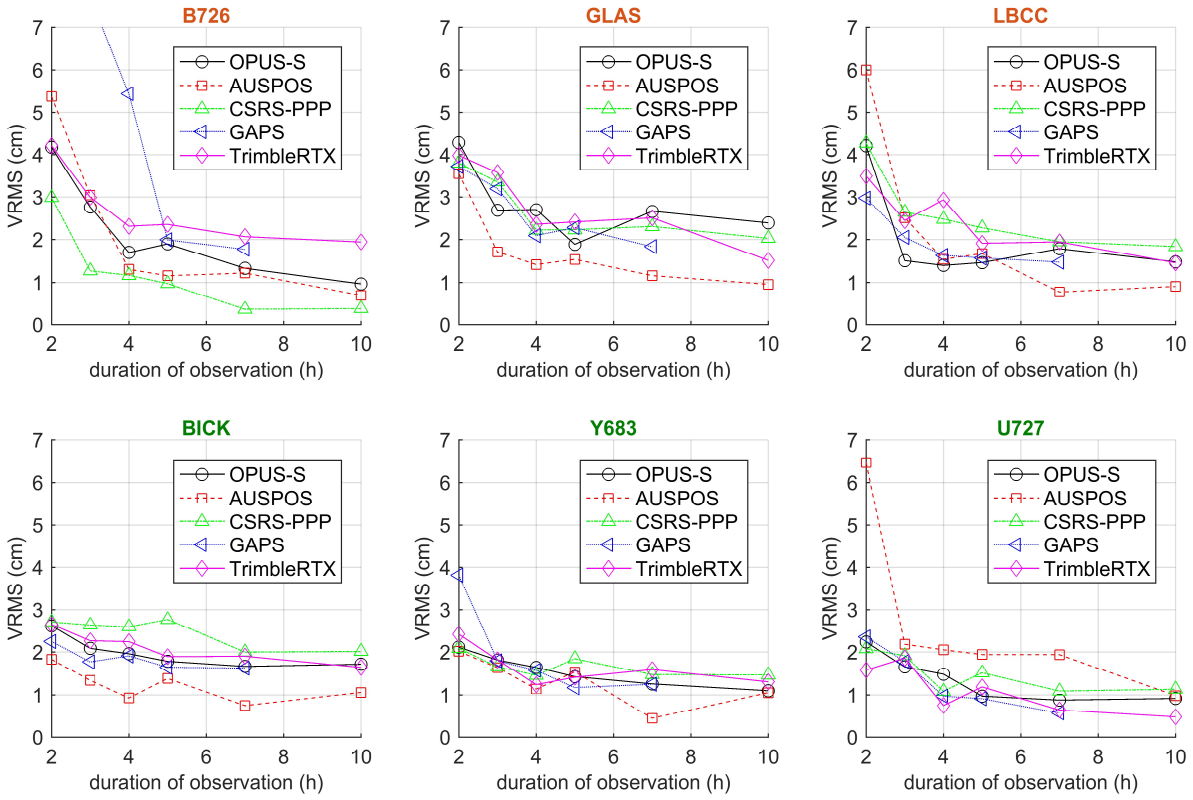




Post-Processing Services Results - VRMS

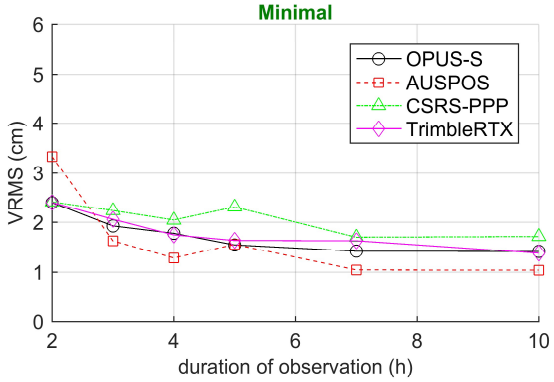
Moderate Obstruction

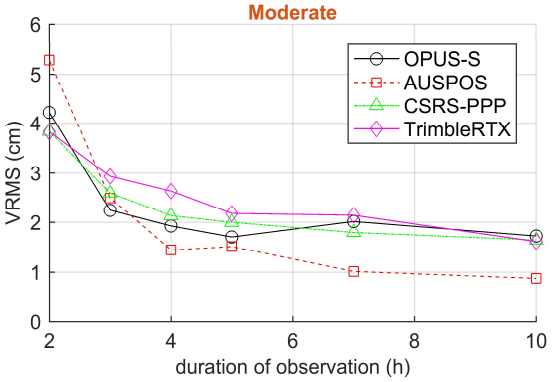
Minimal Obstruction



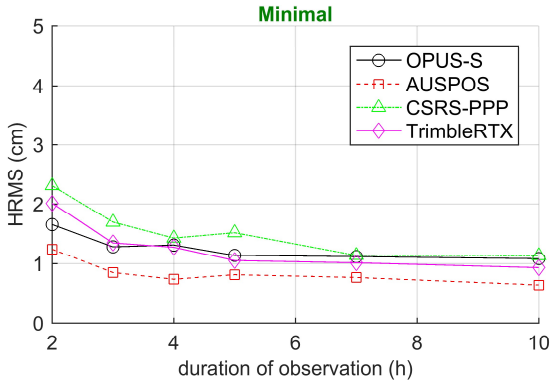
Post- Processing Services → Pooled Samples

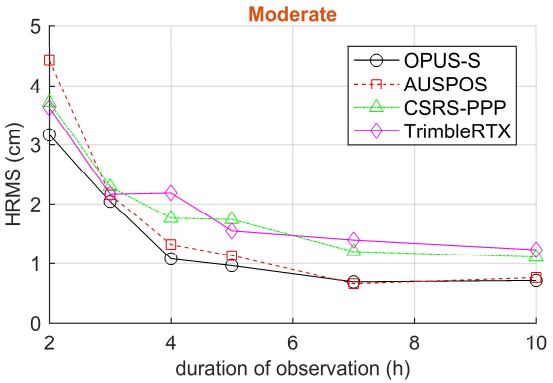
VRMS





HRMS





Objective 2

- Assess impacts of:
  - Faster logging rates
  - Addition of GLONASS observables in 2 services: TrimbleRTX and CSRS-PPP

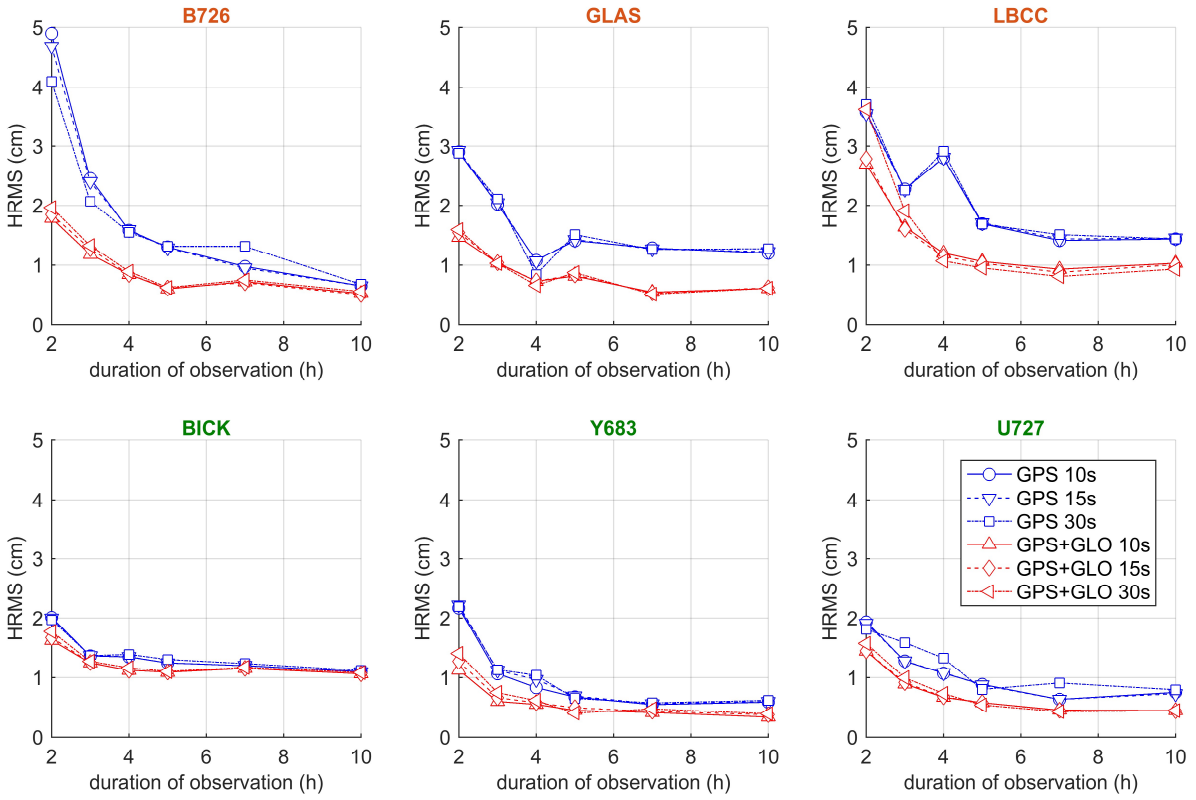
- General takeaway:
  - Faster logging rates marginally improved results
  - Addition of GLONASS observables improved results significantly

TrimbleRTX

HRMS – Faster logging rates, GPS+GLONASS

Moderate Obstruction

Minimal Obstruction

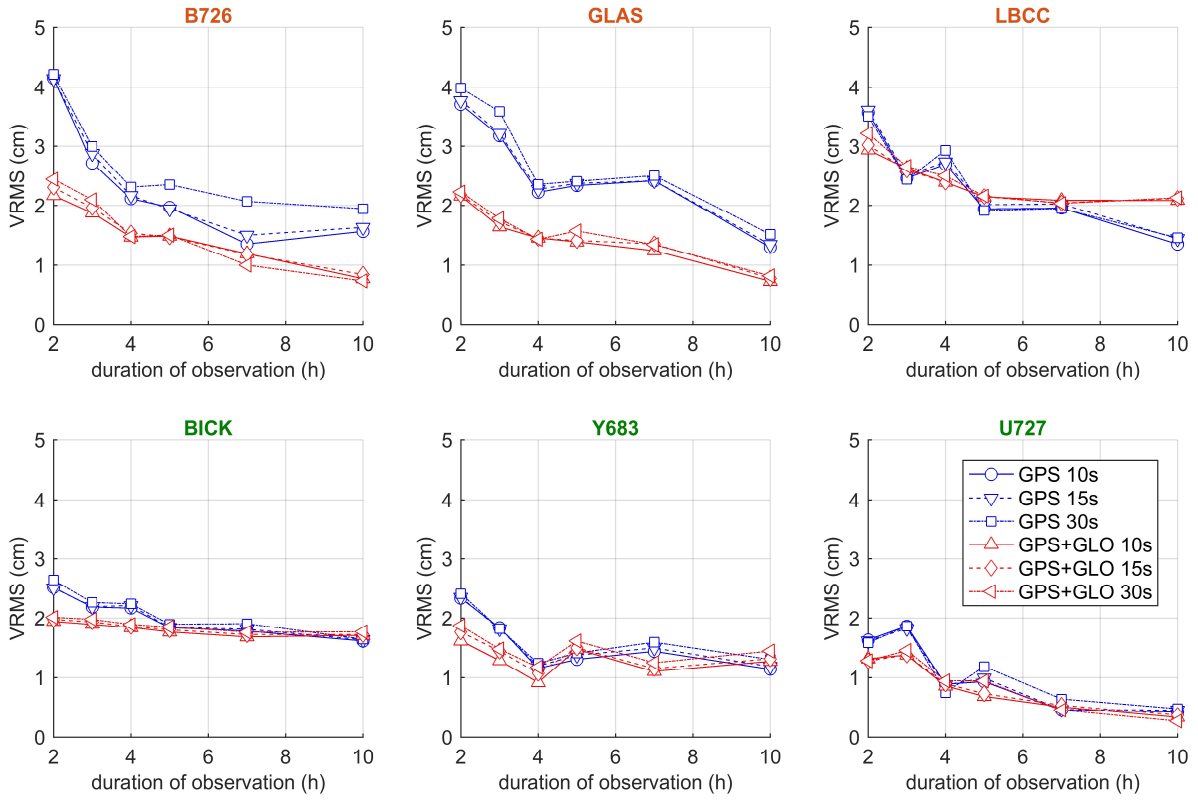


TrimbleRTX

VRMS – Faster logging rates, GPS+GLONASS

Moderate Obstruction

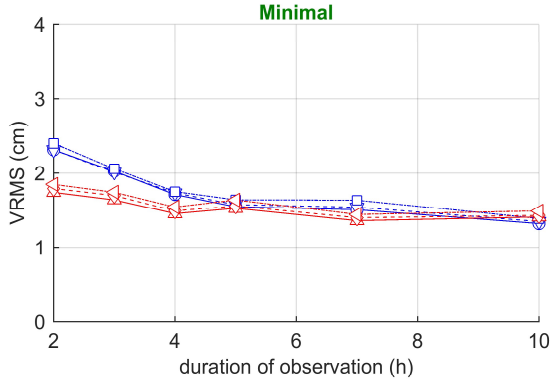
Minimal Obstruction

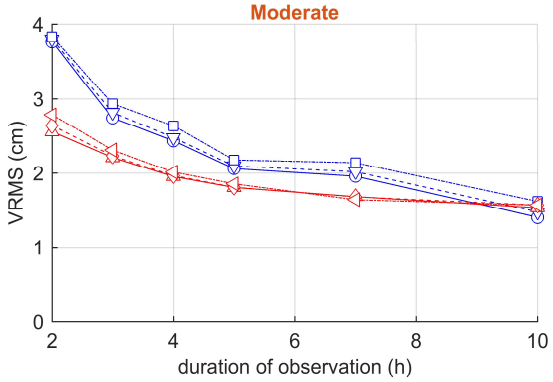


TrimbleRTX

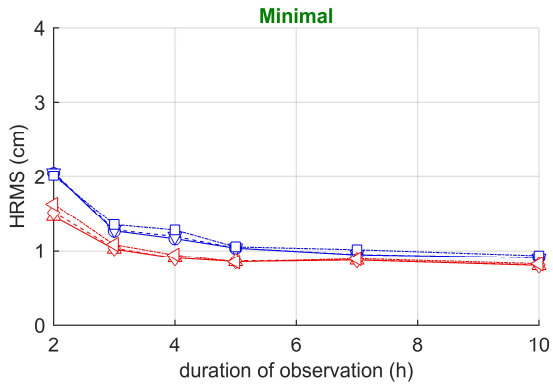
Pooled – Faster logging rates, GPS+GLONASS

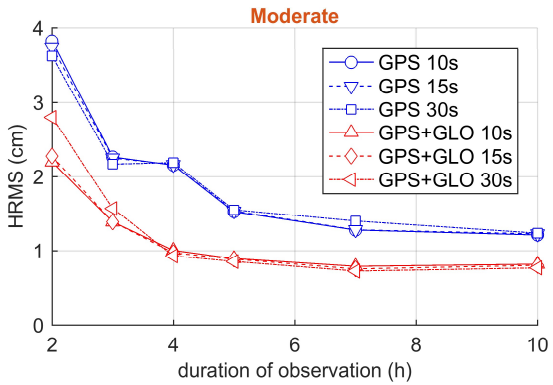
VRMS





HRMS



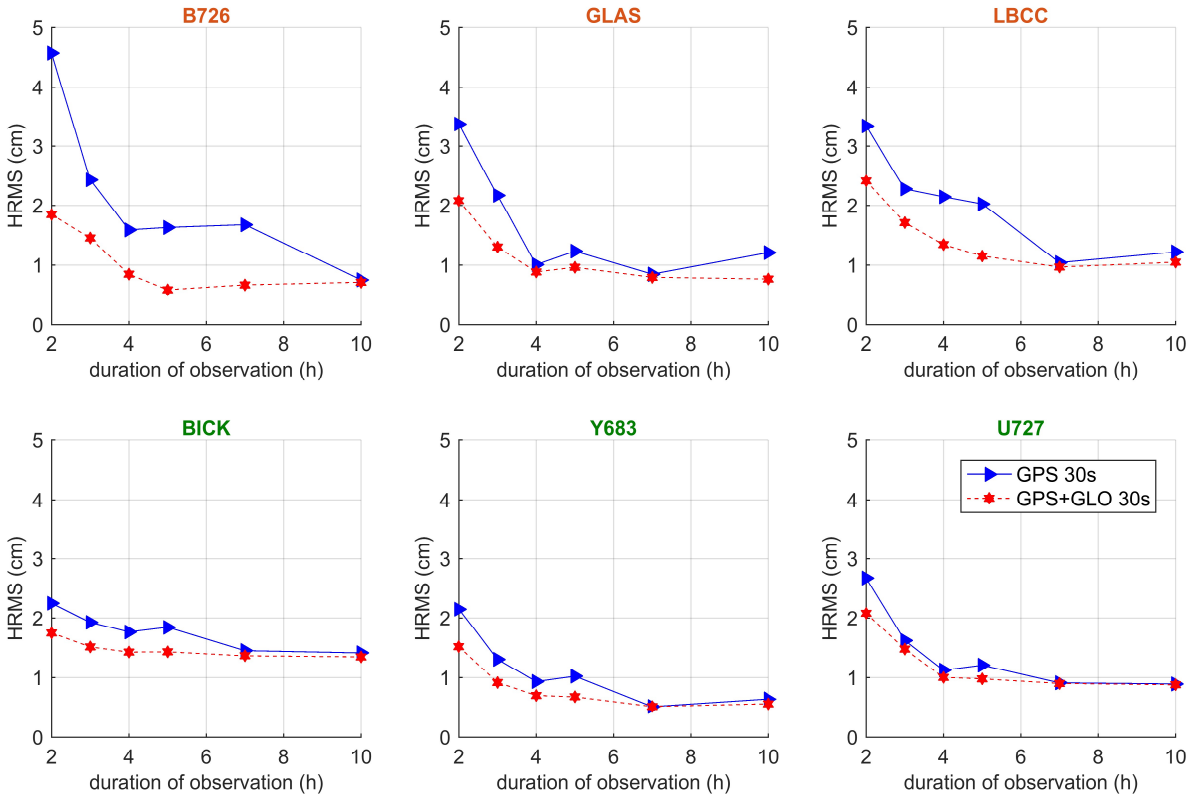


CSRS-PPP

HRMS – GPS+GLONASS

Moderate Obstruction

Minimal Obstruction

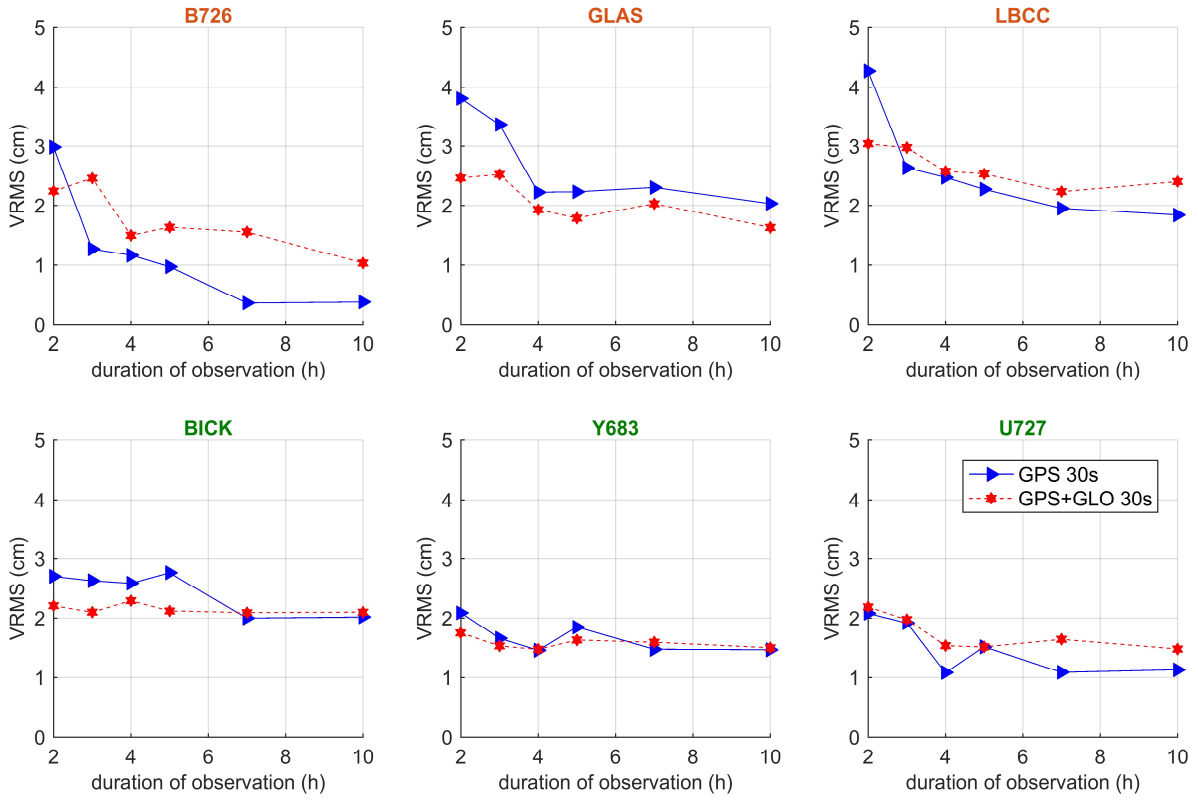


CSRS-PPP

VRMS – GPS+GLONASS

Moderate Obstruction

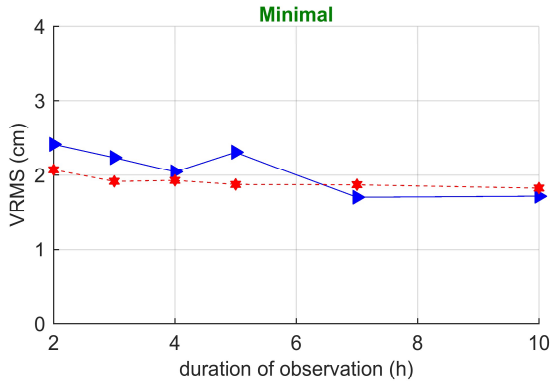
Minimal Obstruction

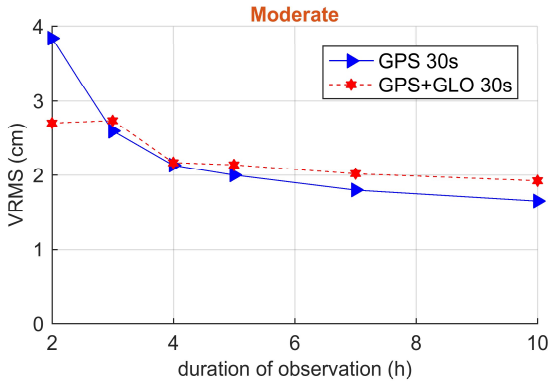


CSRS-PPP

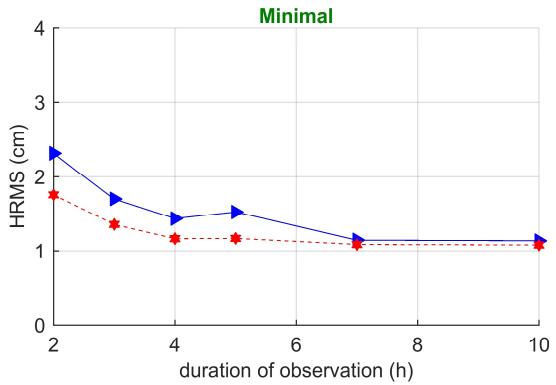
Pooled – GPS+GLONASS

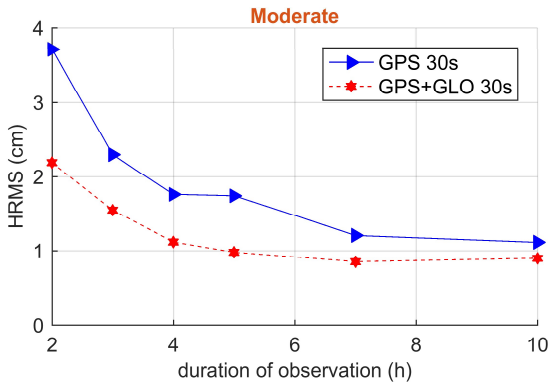
VRMS





HRMS





Conclusions

Conclusions

- All services (except GAPS) have relatively similar results
- 5 hours or greater
  - Services vary by less than 1 cm
  - HRMS and VRMS are similar for minimally and moderately obstructed sites
  - Limited improvement in HRMS or VRMS with longer durations
- Increased logging rates minimally improved results
- Addition of GLONASS reduced RMS by
  - Minimally obstructed
    - HRMS – 17.1%
    - VRMS – 7.7%
  - Moderately obstructed
    - HRMS – 36.7%
    - VRMS – 8.4%

Limitations and Future Work

- All durations tested greater than 2 hours
- All marks in same area
- Only Minimally and Moderately obstructed locations

- Additional services
  - JPL-APPS, SCOUT, MagicGNSS
- Additional/other GNSS constellations
  - Galileo, BeiDou
- Rapid vs Final ephemerides

Acknowledgements

- NOAA
  - Funding
- ODOT, Leica, and David Evans & Associates
  - Equipment for 2014 survey
- Michael Eddy
  - 2014 survey
- Damon Houck
  - Help with submitting files
- Mark Armstrong
  - Special thanks for advice and assistance
- Daniel Gillins, Michael Olsen, and Chris Parrish
  - Special thanks for the support, advice, help, and time

Questions?

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Jamieson, M., & Gillins, D.T., (In Press). Comparative Analysis of Online Static GNSS Post-Processing Services, ASCE Journal of Surveying Engineering.

Additional Info

Further Reading

- Paper in press
  - Jamieson, M., & Gillins, D.T., (In Press). Comparative Analysis of Online Static GNSS Post-Processing Services, ASCE Journal of Surveying Engineering.
- Preliminary Study
  - http://gpsworld.com/a-comparison-of-free-gps-online-post-processing-services/

Comparative Analysis of Online Static GNSS Postprocessing Services

Marian Jamieson[1]; and Daniel T. Gillins, Ph.D., P.L.S., M.ASCE[2]

Abstract: Several precise point positioning or relative positioning services are available online for postprocessing static global navigation satellite system (GNSS) data collected on a single mark. The accuracy of five services (OPUS-S, AUSPOS, CSRS-PPP, GAPS, TrimbleRTX) were compared by processing the same 490 static GNSS files of varying session duration (from 2 to 10 h) on six passive marks in minimal or moderate multipathing environments. First, only Global Positioning System observables at a 30-s logging rate were tested using each service. Then, the effects of including observables from Russia's GNSS (i.e., GLONASS) were investigated using TrimbleRTX and CSRS-PPP, and the accuracy of processing data at faster logging rates were evaluated using TrimbleRTX. The results from each service were differenced with coordinates derived from a high-accuracy campaign-style static GNSS survey. Increasing the logging rate from 30 to 10 s did not significantly reduce the root-mean-square error (RMS) of the differences. However, adding GLONASS observables significantly reduced the horizontal RMS by an average of 17.1% and 36.7% at sites in minimal and moderate multipathing environments, respectively. **DOI:** 10.1061/(ASCE)SU.1943-5428.0000256.

Author keywords: GNSS; GPS; Precise point positioning; PPP; OPUS.

OPUS-Static

Upload your data file.

Solve your GPS position & tie it to the National Spatial Reference System.

What is OPUS? **FAQs**

Choose File No file chosen

* **data file** of dual-frequency GPS observations. **sample**

sample solutions

NONE

antenna - choosing wrong may degrade your accuracy.

0.000 *meters above your mark.*

antenna height of your antenna's reference point.

* **email address** - your solution will be sent here. **Privacy Act Statement**

Options to **customize** your solution.

Upload to Rapid-Static
for data 15 min. - 2 hrs.

Upload to Static
for data 2 hrs. - 48 hrs.

* required fields

We may use your data for internal evaluations of OPUS use, accuracy, or related research.

FILE: BICKD1.14o OP1415139856075

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: marianberryjam@gmail.com DATE: November 04, 2014
RINEX FILE: bick195p.14o TIME: 22:31:21 UTC

SOFTWARE: page5 1209.04 master50.pl 022814 START: 2014/07/14 15:57:00
EPHEMERIS: igs18011.eph [precise] STOP: 2014/07/14 22:45:00
NAV FILE: brdc1950.14n OBS USED: 19415 / 19989 : 97%
ANT NAME: LEIGS14 NONE # FIXED AMB: 77 / 79 : 97%
ARP HEIGHT: 2.000 OVERALL RMS: 0.012(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2014.5337)

X:	-2500921.806(m)	0.005(m)	-2500922.661(m)	0.005(m)
Y:	-3810086.831(m)	0.010(m)	-3810085.615(m)	0.010(m)
Z:	4447093.914(m)	0.013(m)	4447093.943(m)	0.013(m)

LAT:	44 29 22.26003	0.006(m)	44 29 22.27313	0.006(m)
E LON:	236 43 9.50467	0.006(m)	236 43 9.44212	0.006(m)
W LON:	123 16 50.49533	0.006(m)	123 16 50.55788	0.006(m)
EL HGT:	52.347(m)	0.014(m)	51.977(m)	0.014(m)
ORTHO HGT:	75.102(m)	0.028(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES (UTM (Zone 10))	STATE PLANE COORDINATES (SPC (3601 OR N))
Northing (Y) [meters]	4926283.030	95243.437
Easting (X) [meters]	477681.526	2278864.625
Convergence [degrees]	-0.19670460	-1.97202870
Point Scale	0.99960613	0.99996433
Combined Factor	0.99959793	0.99995612

US NATIONAL GRID DESIGNATOR: 10TDQ7768126283(NAD 83)

BASE STATIONS USED

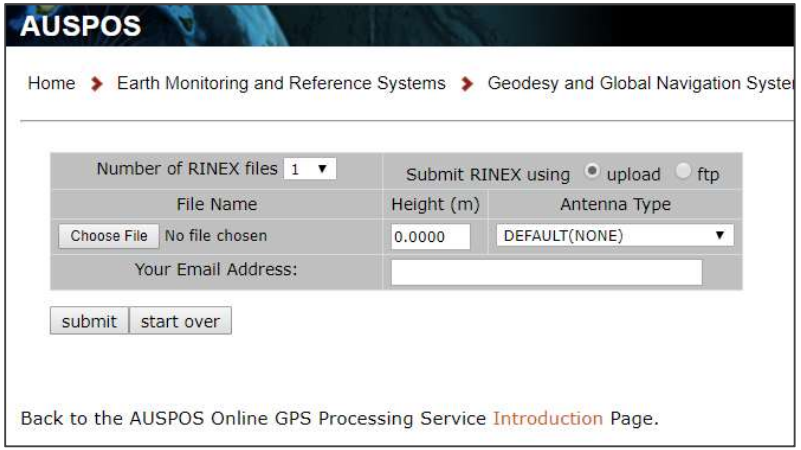
PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DO8790	RSBG ROSEBURG CORS ARP	N431406.050	W1232133.727	139529.9
DN2111	JIME JIM ELAM CORS ARP	N453123.214	W1225925.841	117120.9
AH2507	REDM REDMOND CORS ARP	N441535.146	W1210852.315	171897.3

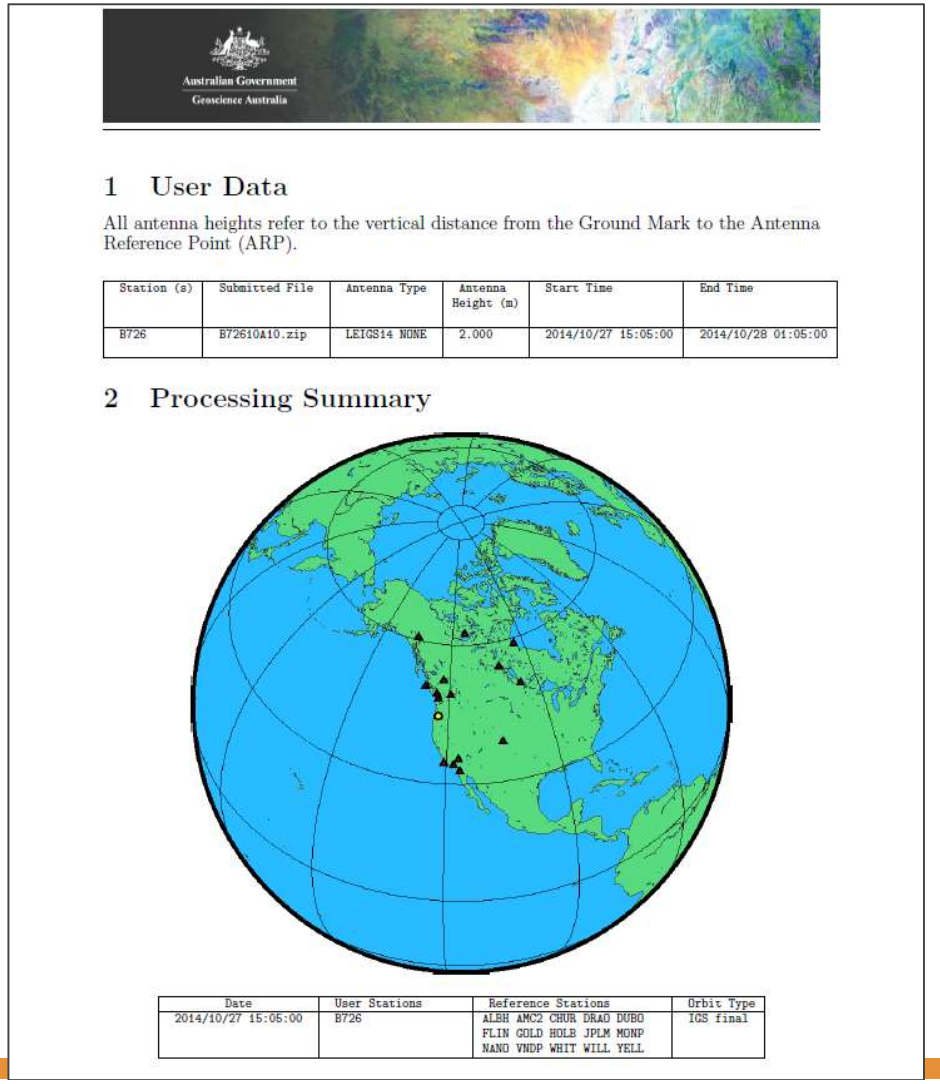
NEAREST NGS PUBLISHED CONTROL POINT

QE0656	BICKFORD	N442922.260	W1231650.495	0.0

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

AUSPOS


AUSPOS
Home
Earth Monitoring and Reference Systems
Geodesy and Global Navigation Syste
Number of RINEX files 1
Submit RINEX using upload ftp
File Name
Height (m)
Antenna Type
Choose File No file chosen
0.0000
DEFAULT(NONE)
Your Email Address:
submit
start over
Back to the AUSPOS Online GPS Processing Service Introduction Page.


Australian Government
Geoscience Australia
1 User Data
All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).
Station (s) | Submitted File | Antenna Type | Antenna Height (m) | Start Time | End Time
B726 | B72610A10.zip | LEIGS14 NONE | 2.000 | 2014/10/27 15:05:00 | 2014/10/28 01:05:00
2 Processing Summary
Date | User Stations | Reference Stations | Orbit Type
2014/10/27 15:05:00 | B726 | ALBH AMC2 CHUR DRAO DUBO FLIN GOLD HOLB JPLM MONP NANO VNDP WHIT WILL YELL | IGS final

CSRS-PPP

Precise Point Positioning

► Help for CSRS PPP (**Updated 2017-01-26**)

Profile | Sign out

Email for results (required)

marianberryjam@gmail.com

Processing mode

◉ Static ○ Kinematic

NAD83 | ITRF

- The epoch will be the same as the GPS data.
- A UTM zone will be calculated from the longitude.

Vertical datum

CGVD2013

Contribute to passive control maintenance? (what is this?)

☐ Authorize the Canadian Geodetic Survey (CGS) to archive and publish CSRS-PPP submission and solution

Official marker station name

► More options

RINEX observation file (required) (.zip, .gzip, .gz, .Z, .??O)

Choose File | No file chosen

Submit to PPP

Use of Canadian Geodetic Survey products and data is subject to the Open Government Licence - Canada

Geodetic Reference Systems Information

NOTE: Canadian NAD83 is not the same as US NAD83.

CSRS-PPP (V 1.05 34613)

B726

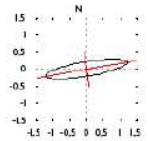
Data Start	Data End	Duration of Observations
2014-10-27 15:05:00.000	2014-10-27 17:06:00.000	2h 0m 60.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.011m		2.0m / 0.786m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	30.00 sec / 30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
LEIGS14 NONE	L1= 0.089 m L2= 0.089 m	2.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for B72602A10G.14o

	Latitude (+n)	Longitude (+e)	Ell. Height
ITRF08 (2014)	44° 38' 54.2665''	-123° 03' 45.5764''	42.009 m
Sigmas(95%)	0.023 m	0.098 m	0.080 m
Apriori	44° 38' 54.281''	-123° 03' 45.532''	41.525 m
Estimated - Apriori	-0.459 m	-0.988 m	0.484 m

95% Error Ellipse (dm)
semi-major: 1.237dm
semi-minor: 0.207dm
semi-major azimuth: 80° 45' 28.22''



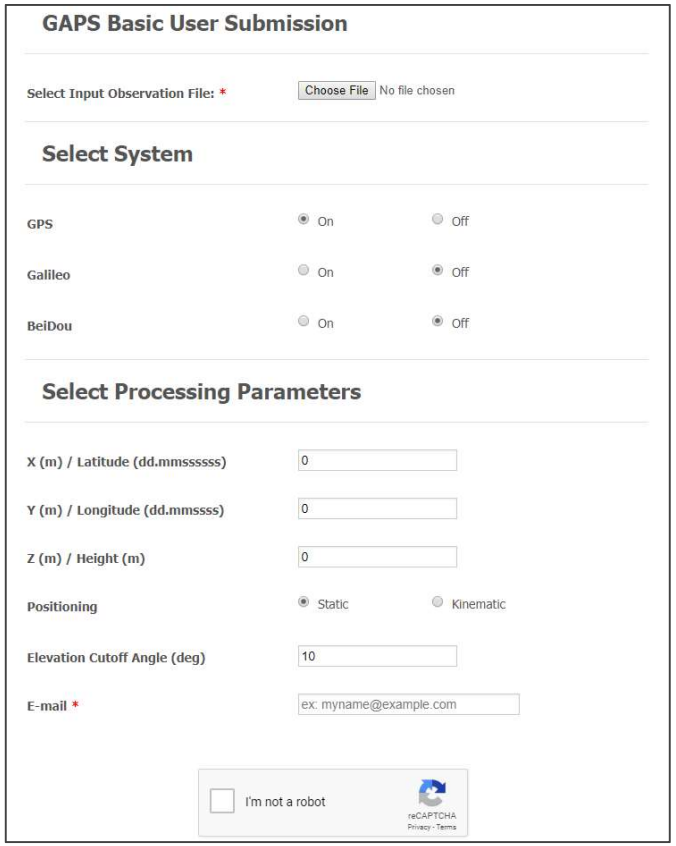
UTM (North) Zone 10

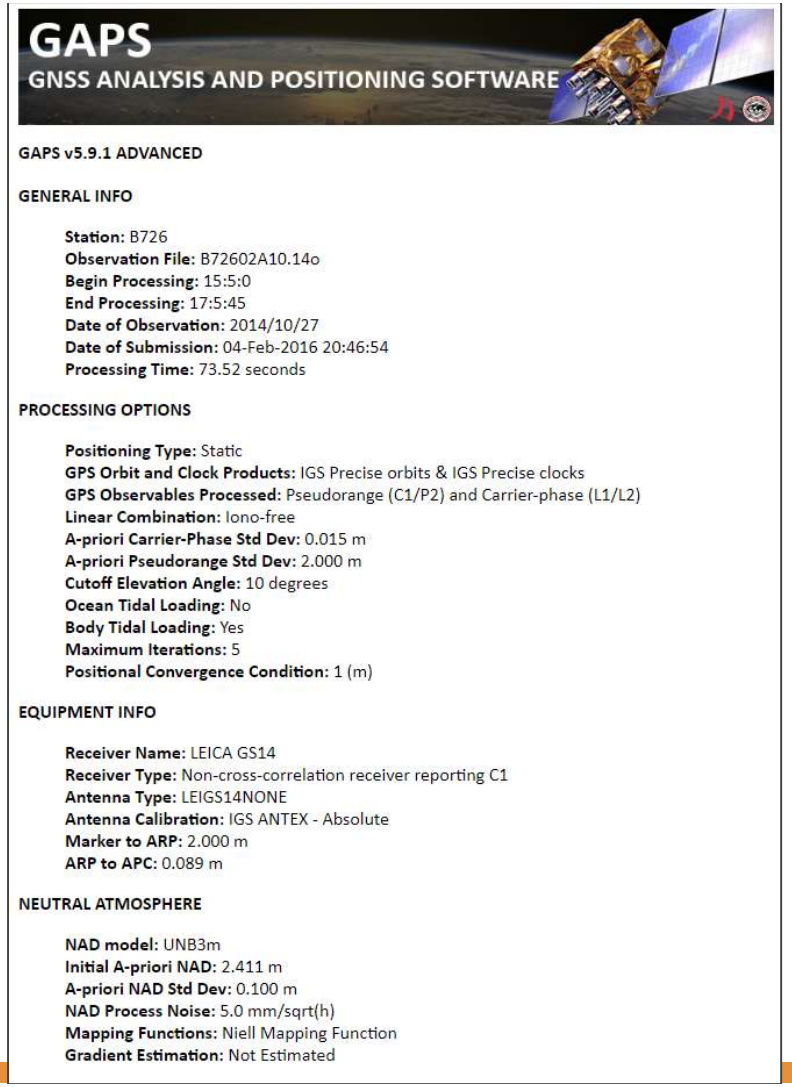
4943896.031m (N) 495031.315m (E)

Scale Factors
0.99960030 (point)
0.99959371 (combined)

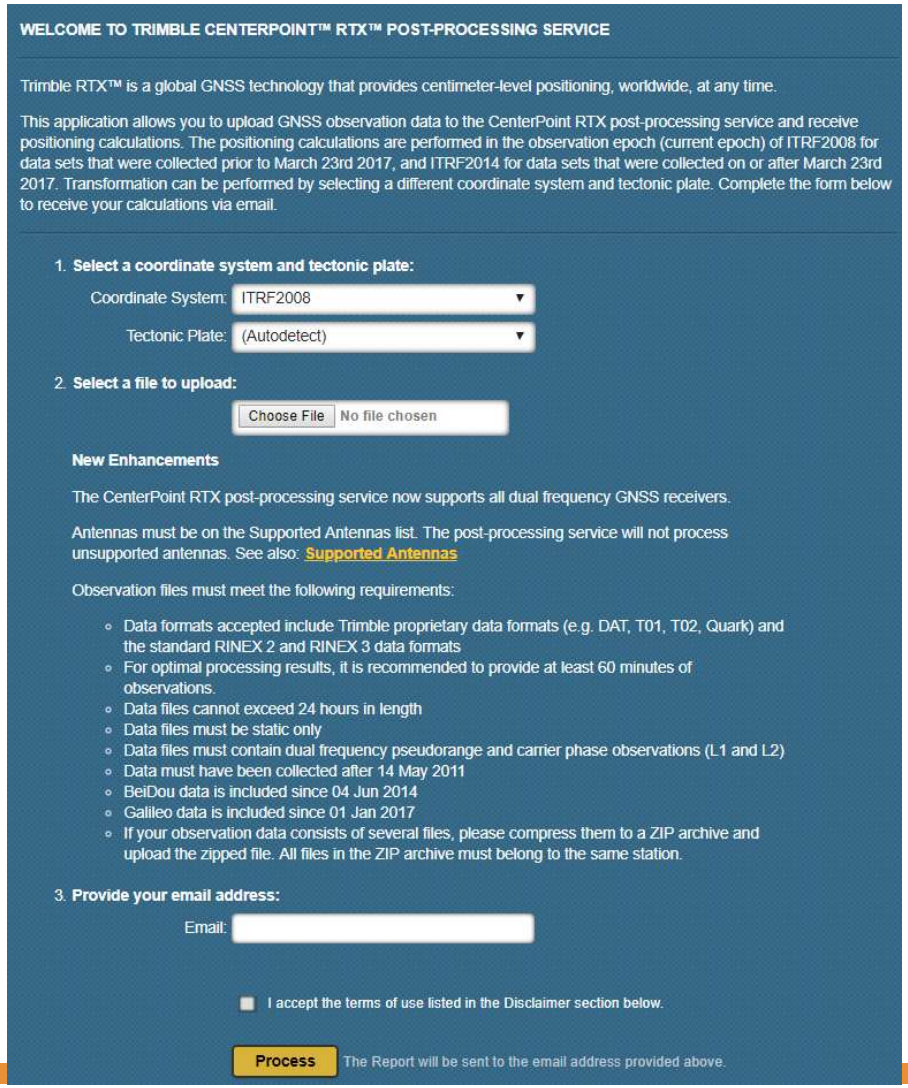
(Coordinates from RINEX file used as apriori position)

GAPS


GAPS Basic User Submission
Select Input Observation File: *
Choose File
No file chosen
Select System
GPS
On
Off
Galileo
On
Off
BeiDou
On
Off
Select Processing Parameters
X (m) / Latitude (dd.mmssssss)
0
Y (m) / Longitude (dd.mmssss)
0
Z (m) / Height (m)
0
Positioning
Static
Kinematic
Elevation Cutoff Angle (deg)
10
E-mail *
ex: myname@example.com
I'm not a robot
reCAPTCHA
Privacy - Terms


GAPS
GNSS ANALYSIS AND POSITIONING SOFTWARE
GAPS v5.9.1 ADVANCED
GENERAL INFO
Station: B726
Observation File: B72602A10.14o
Begin Processing: 15:5:0
End Processing: 17:5:45
Date of Observation: 2014/10/27
Date of Submission: 04-Feb-2016 20:46:54
Processing Time: 73.52 seconds
PROCESSING OPTIONS
Positioning Type: Static
GPS Orbit and Clock Products: IGS Precise orbits & IGS Precise clocks
GPS Observables Processed: Pseudorange (C1/P2) and Carrier-phase (L1/L2)
Linear Combination: Iono-free
A-priori Carrier-Phase Std Dev: 0.015 m
A-priori Pseudorange Std Dev: 2.000 m
Cutoff Elevation Angle: 10 degrees
Ocean Tidal Loading: No
Body Tidal Loading: Yes
Maximum Iterations: 5
Positional Convergence Condition: 1 (m)
EQUIPMENT INFO
Receiver Name: LEICA GS14
Receiver Type: Non-cross-correlation receiver reporting C1
Antenna Type: LEIGS14NONE
Antenna Calibration: IGS ANTEX - Absolute
Marker to ARP: 2.000 m
ARP to APC: 0.089 m
NEUTRAL ATMOSPHERE
NAD model: UNB3m
Initial A-priori NAD: 2.411 m
A-priori NAD Std Dev: 0.100 m
NAD Process Noise: 5.0 mm/sqrt(h)
Mapping Functions: Niell Mapping Function
Gradient Estimation: Not Estimated

TrimbleRTX



WELCOME TO TRIMBLE CENTERPOINT™ RTX™ POST-PROCESSING SERVICE

Trimble RTX™ is a global GNSS technology that provides centimeter-level positioning, worldwide, at any time.

This application allows you to upload GNSS observation data to the CenterPoint RTX post-processing service and receive positioning calculations. The positioning calculations are performed in the observation epoch (current epoch) of ITRF2008 for data sets that were collected prior to March 23rd 2017, and ITRF2014 for data sets that were collected on or after March 23rd 2017. Transformation can be performed by selecting a different coordinate system and tectonic plate. Complete the form below to receive your calculations via email.

1. **Select a coordinate system and tectonic plate:**

Coordinate System: ITRF2008

Tectonic Plate: (Autodetect)

2. **Select a file to upload:**

Choose File No file chosen

New Enhancements

The CenterPoint RTX post-processing service now supports all dual frequency GNSS receivers.

Antennas must be on the Supported Antennas list. The post-processing service will not process unsupported antennas. See also: Supported Antennas

Observation files must meet the following requirements:

- Data formats accepted include Trimble proprietary data formats (e.g. DAT, T01, T02, Quark) and the standard RINEX 2 and RINEX 3 data formats
- For optimal processing results, it is recommended to provide at least 60 minutes of observations.
- Data files cannot exceed 24 hours in length
- Data files must be static only
- Data files must contain dual frequency pseudorange and carrier phase observations (L1 and L2)
- Data must have been collected after 14 May 2011
- BeiDou data is included since 04 Jun 2014
- Galileo data is included since 01 Jan 2017
- If your observation data consists of several files, please compress them to a ZIP archive and upload the zipped file. All files in the ZIP archive must belong to the same station.

3. **Provide your email address:**

Email:

I accept the terms of use listed in the Disclaimer section below.

Process The Report will be sent to the email address provided above.

TrimbleRTX

Raw XML file

```
<?xml version="1.0" encoding="UTF-8"?>
<TRIMBLE_RTX_SOLUTION SID="7136109" REFERENCE_NUMBER="B72603A10G.zip" SOFTWARE_VERSION="5.0.0.151
 <SOLUTION_TIME>2016-05-12T00:27:31Z</SOLUTION_TIME>
 <OBSERVATION_TIME START="2014-10-27T15:05:00Z" END="2014-10-27T18:05:00Z" />
 <CONTRIBUTOR>
   <EMAIL>marianberryjam@gmail.com</EMAIL>
 </CONTRIBUTOR>
 <DATA_SOURCES>
   <OBS_FILE TYPE="RINEX">B72603A10G.14o</OBS_FILE>
   <ANTENNA>
     <NAME>LEIGS14          NONE</NAME>
     <ARP_HEIGHT UNIT="m">2.000</ARP_HEIGHT>
     <REFERENCE>Bottom of antenna mount</REFERENCE>
   </ANTENNA>
   <RECEIVER>
     <NAME>LEICA GS14</NAME>
   </RECEIVER>
 </DATA_SOURCES>
 <DATA_QUALITY>
   <ACCURACY UNIT="m">
     <LAT>0.008</LAT>
     <LONG>0.043</LONG>
     <EL_HEIGHT>0.021</EL_HEIGHT>
   </ACCURACY>
   <PERCENT_OBS_USED TOTAL="361" PROCESSING_INTERVAL="30.0" USABLE="361" USED="356">98</PERCENT_
   <USED_SATELLITES TOTAL="10" GPS_SV="G02 G05 G06 G10 G12 G17 G24 G25 G29 G31" QZSS_SV="" GLN_S
 </DATA_QUALITY>
 <POSITION TYPE="INTERNAL">
   <REF_FRAME>ITRF2008</REF_FRAME>
   <TECTONIC_PLATE MODEL="MORVEL56" AUTO_DETECTED="True">North America</TECTONIC_PLATE>
   <EPOCH>2014.82</EPOCH>
   <COORD_SET>
     <RECT_COORD>
       <COORDINATE AXIS="X" UNIT="m" UNCERTAINTY="0.040">-2479641.015</COORDINATE>
       <COORDINATE AXIS="Y" UNIT="m" UNCERTAINTY="0.022">-3809185.606</COORDINATE>
       <COORDINATE AXIS="Z" UNIT="m" UNCERTAINTY="0.016">4459665.366</COORDINATE>
     </RECT_COORD>
     <ELLIP_COORD>
       <LAT>
         <DEGREES>44</DEGREES>
         <MINUTES>38</MINUTES>
         <SECONDS>54.26676</SECONDS>
       </LAT>
       <EAST_LONG>
```

Formatted XML

Trimble

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor:	dtgillins@gmail.com
Reference Name:	Y68302A06V.zip
Upload Date:	06/30/2016 21:35:50 UTC
Report Time Frame:	
Start Time:	10/13/2014 14:29:00 UTC
End Time:	10/13/2014 16:29:00 UTC
Observation File Type(s):	RINEX
Observation File(s):	Y68302A06V.14o
Antenna:	
Name:	LEIGS14 NONE
Height:	2.000 m
Reference:	Bottom of antenna mount
Receiver Name:	LEICA GS14
Coordinate Systems:	NAD83-2011 & ITRF2008
Tectonic Plate:	North America
Tectonic Plate Model:	MORVEL56
Processing Interval:	10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
1441	720	710	98

Used Satellites

# Total Satellites:	19
GPS:	G01 G02 G04 G06 G12 G15 G17 G24 G25 G26 G28
GLONASS:	R12 R13 R14 R15 R17 R22 R23 R24

Processing Results

NAD83-2011 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	-2488287.242 m	0.027 m
Y	-3799765.128 m	0.026 m
Z	4462905.913 m	0.012 m
Latitude	44° 41' 20.91988" N	0.009 m
Longitude	123° 13' 8.04300" W	0.035 m
El. Height	72.014 m	0.017 m

ITRF2008 at Epoch 2014.78		
Coordinate	**Value**	**σ**
X	-2488288.135 m	0.027 m
Y	-3799763.936 m	0.026 m
Z	4462905.903 m	0.012 m
Latitude	44° 41' 20.93123" N	0.009 m
Longitude	123° 13' 8.10657" W	0.035 m
El. Height	71.645 m	0.017 m

Report Information

Trimble RTX Solution ID:	7249771
Solution Type:	Static
Software Version:	5.0.0.15127
Creation Date:	06/30/2016 21:36:14 UTC

Bias Study

$$RMS = \sqrt{\mu^2 + \sigma^2}$$

$$\mu_n = \sqrt{|NRMS^2 - \sigma_n^2|}$$

$$\mu_e = \sqrt{|ERMS^2 - \sigma_e^2|}$$

$$\mu_u = \sqrt{|VRMS^2 - \sigma_u^2|}$$

Table 4. Summary of F-test results for pooled observations

Service	# rejects out of 12			Total
	North	East	Up	
OPUS-S	8	2	4	*14 / 36*
AUSPOS	2	0	0	*2 / 36*
CSRS-PPP	8	1	7	*16/ 36*
TrimbleRTX	6	0	0	*6 / 36*
total	*24 / 48*	*3 / 48*	*11 / 48*	*38 / 144*