NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

CSRS-PPP – Transitioning to a Modernized Positioning Service in Canada

SLSA AGM
June 12, 2019

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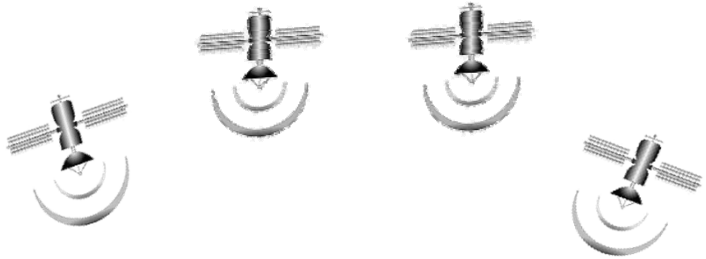
Canadian Geodetic Survey, Surveyor General Branch

Outline

- CSRS-PPP overview
  - History of CSRS-PPP
  - Submission options
  - Usage statistics
- August 2018 software update
  - Rationale
  - Accuracy analysis
  - User impact
- CSRS-PPP solution validation
- Future plans

CSRS-PPP Overview



NRCan or IGS

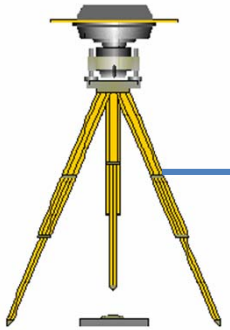
GNSS Orbit & Clock Estimation

NRCan

GNSS Modelling and Processing

CSRS-PPP

IGS



GNSS RINEX Data

Estimated Static or Kinematic Positions

Users

*PPP Coordinates are in the reference system of the orbit and clock products

CSRS-PPP – Product Summary

Product	Frequency	Latency[1]	Hor. RMS[2]	Ver. RMS[2]	Usage (2018)
NRCan Ultra-Rapid GNSS	Hourly[3]	90 minutes	10 mm	13 mm	8%
NRCan Rapid GNSS	Daily	12 – 15 hours	10 mm	13 mm	34%
IGS Final GNSS	Weekly	12 – 15 days	9 mm	10 mm	58%

[1] Latency is measured from the end of the time correction period

[2] Horizontal and Vertical RMS were calculated from static PPP results for 1013 RINEX files with 3-hour observations

[3] GLONASS Ultra-Rapid currently on 3 hour cycle (will be updated to hourly in 2019)

CSRS-PPP – History

Date	Update
2003-10-14[1]	**CSRS-PPP service launched with GPSPACE software**
2006-12-05	Introduced multi-file submissions
2008-05-12	Ultra-rapid products introduced
2009-09-09	Introduced epoch transformations for NAD83(CSRS) solutions
2011-10-04	Introduced GLONASS processing
2012-10-19	National velocity grid updated to version 6.0
2013-11-29	Added option to get orthometric heights in CGVD2013
2015-10-21	Implemented queuing system to reduce wait times during peak periods
2018-08-16[2]	**Transitioned processing engine from GPSPACE to SPARK**
2019-02-14	National velocity grid updated to version 7.0

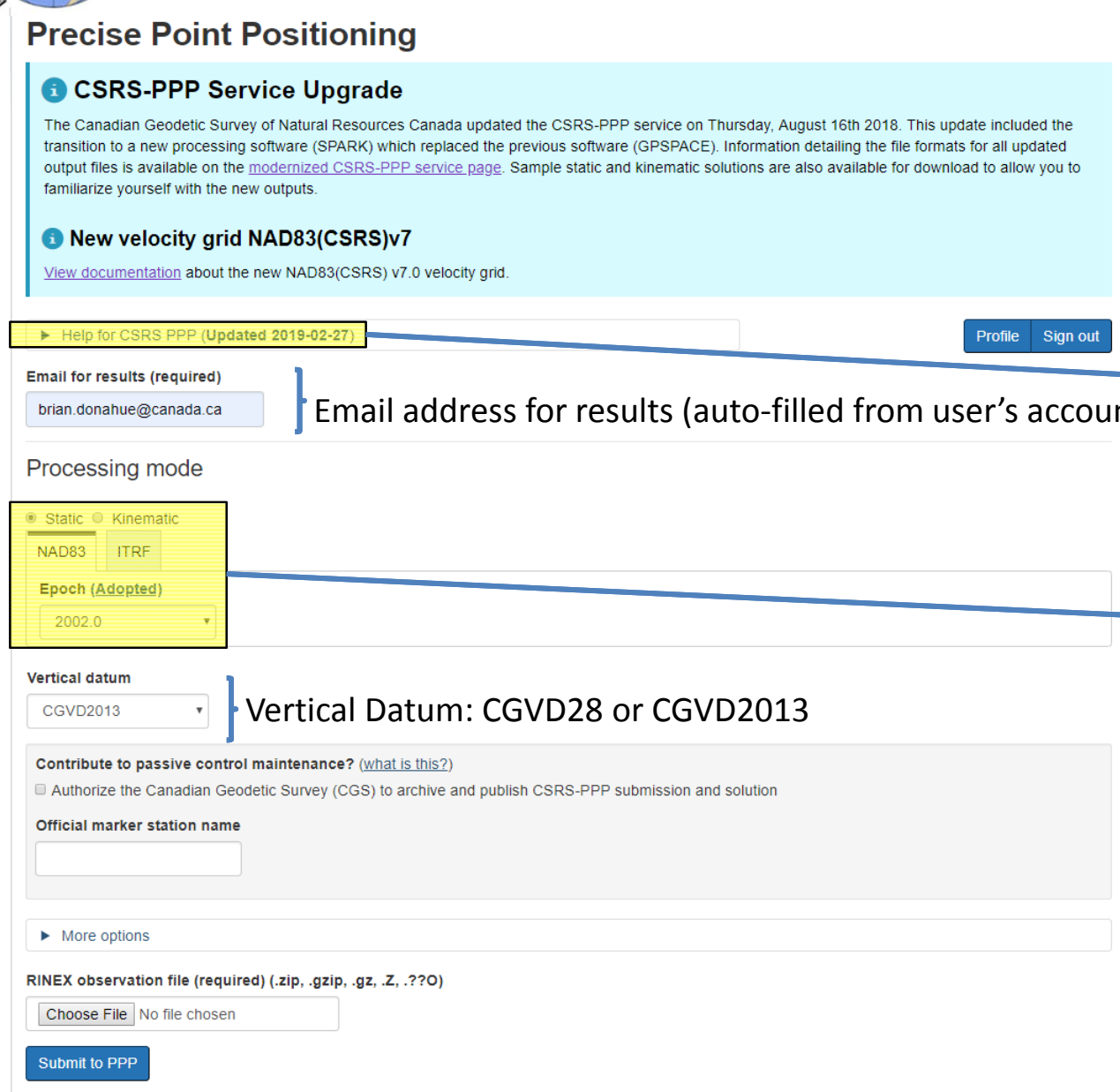
[1] Processed 547 RINEX files during 1st month of CSRS-PPP service

[2] Processed 49,500+ RINEX files during 1st month with SPARK

CSRS-PPP – Submission Options

Option	Notes
Web interface	• https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php • Can upload either single or multiple (tar or zip archive) RINEX files • Maximum file size limit of 300 MB • Results (link) will be emailed when analysis completed
PPP direct	• https://webapp.geod.nrcan.gc.ca/geod/tools-outils/applications.php • Desktop application which can be installed on PC (Windows only) • Can drag and drop single or multiple RINEX files • Allows for direct download and/or email of results • Limit of 5 RINEX files for direct download
Script	• CSRS-PPP runs as a web service and submissions can be automated • Requires network connectivity while files are being processed

CSRS-PPP – Web Interface



Important notices with links to documentation

Help Link: Lists all major changes to service

Email address for results (auto-filled from user's account)

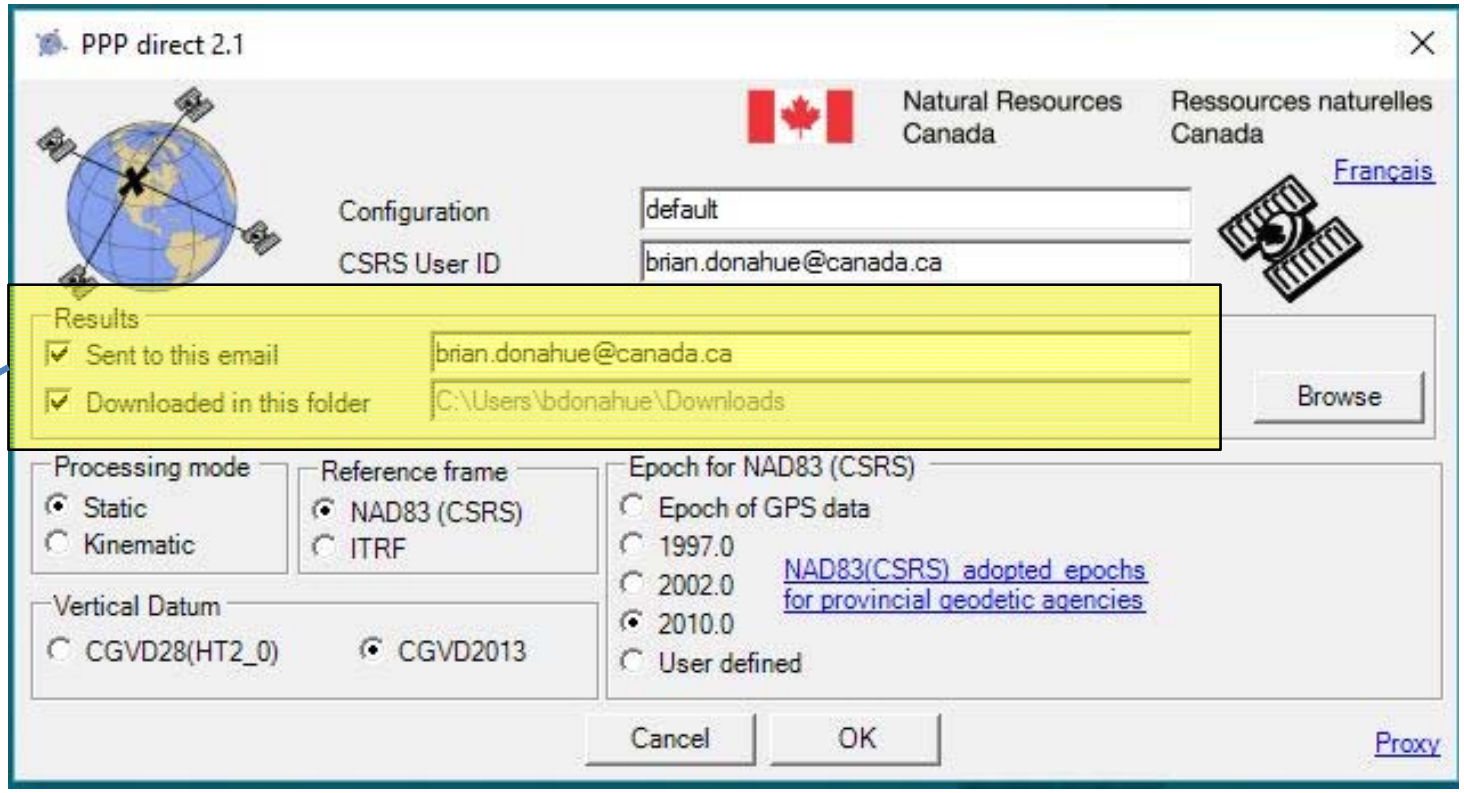
Pick mode, reference frame, epoch (if NAD83 ref. frame)

Vertical Datum: CGVD28 or CGVD2013

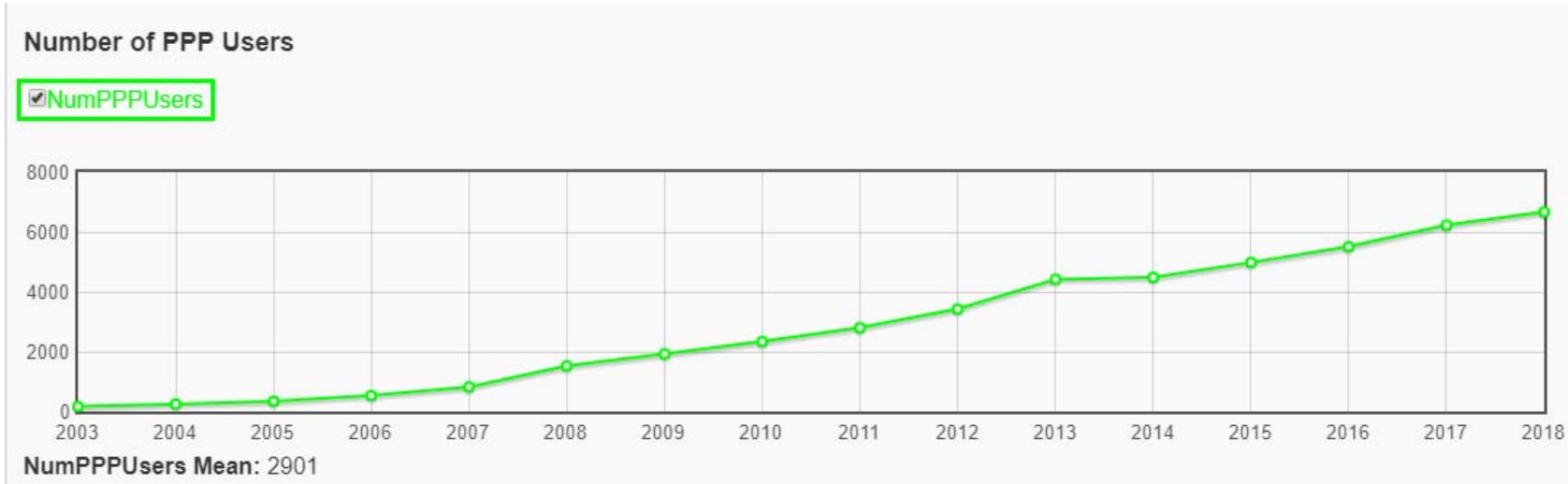
If submitting data collected on an existing passive control monument, user can request to have it archived for possible coordinate maintenance

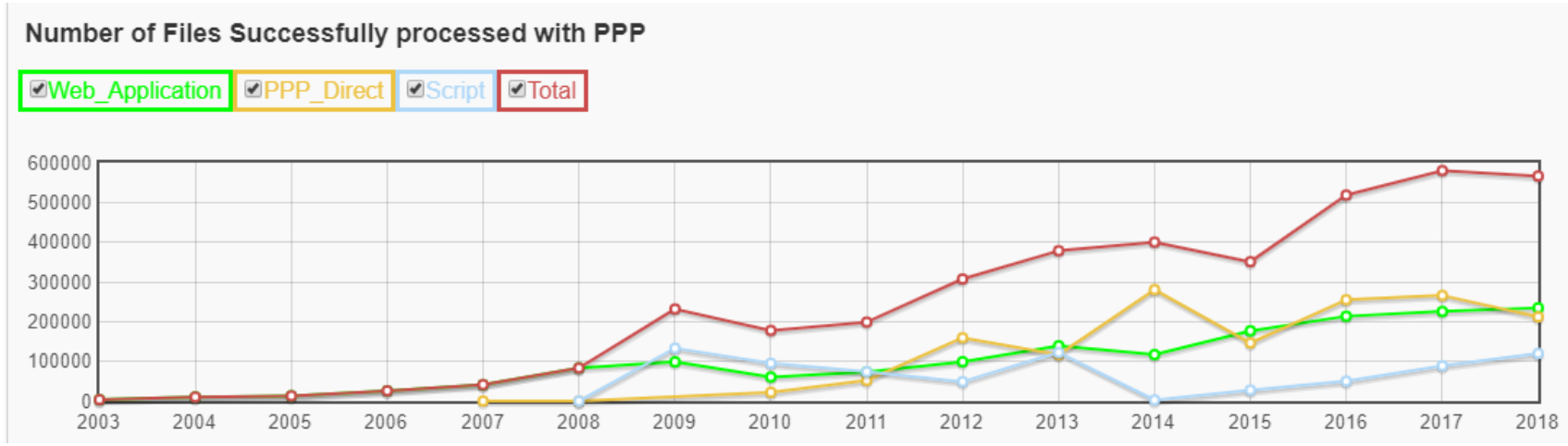
CSRS-PPP – PPP direct Application

User can select local directory and/or email return



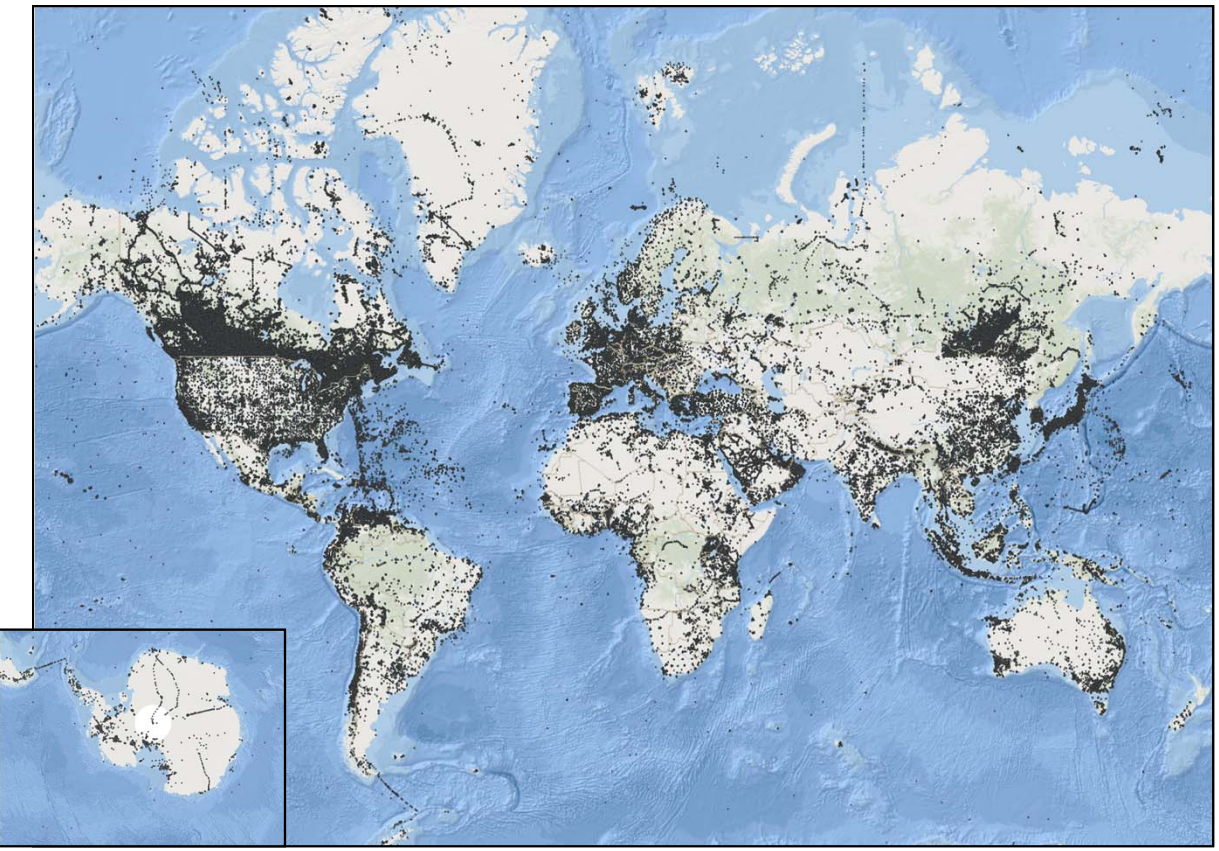
CSRS-PPP Global Usage 2003-2019





CSRS-PPP Worldwide usage

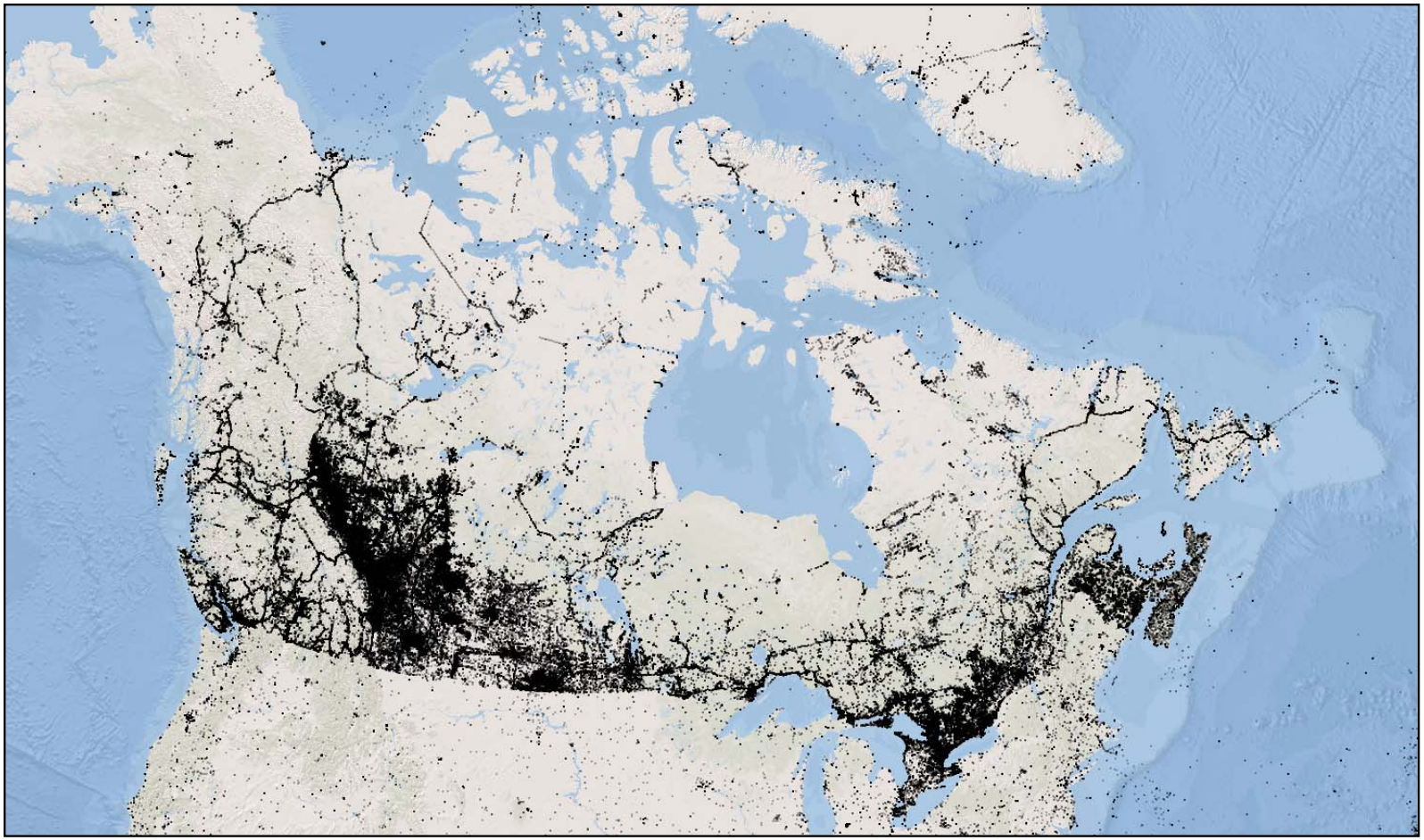
2003 - 2018



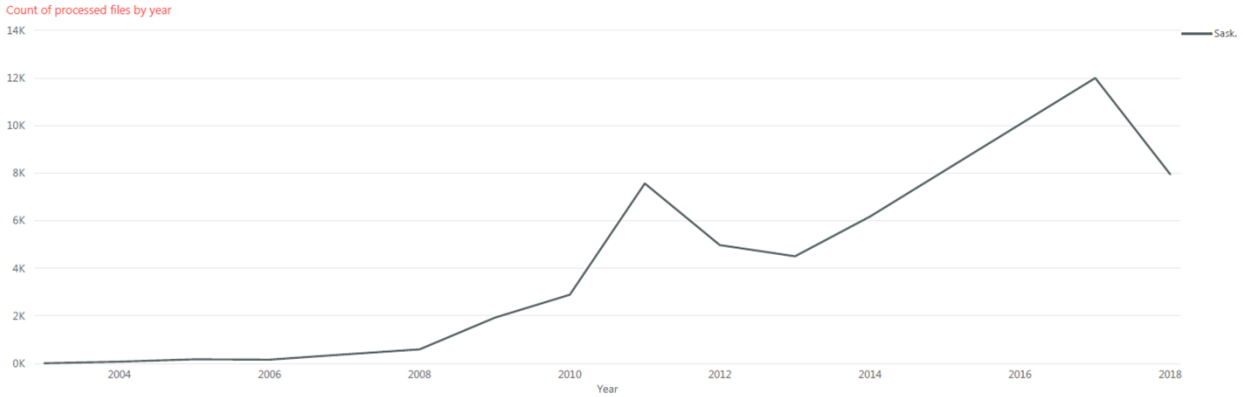
- 3.2M successfully processed files
- 21.3K users
- 203 countries/terr.
- 779K (25%) in Canada

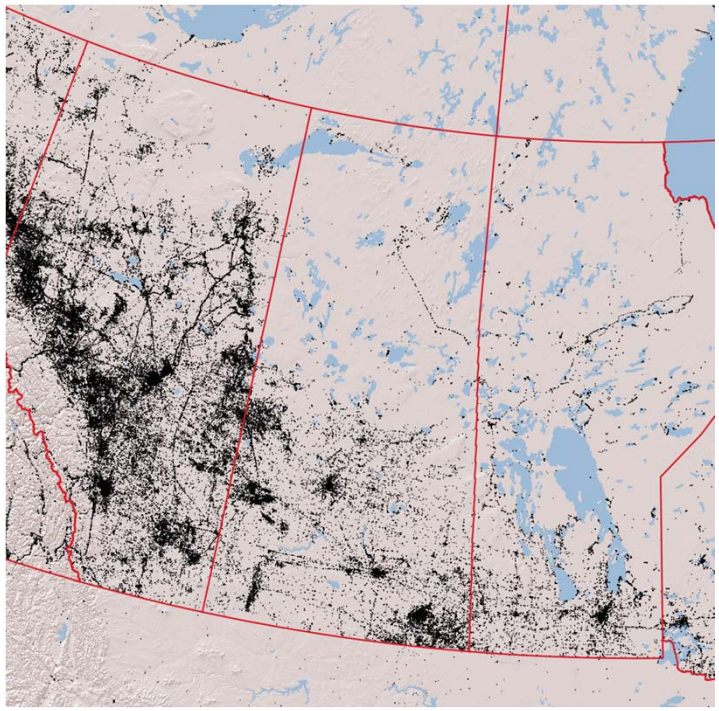
(Basemap : ESRI)

CSRS-PPP Canadian Usage 2003-2018

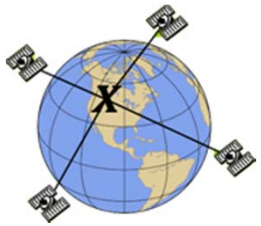


CSRS-PPP Sask. Usage (2003-2018)





Files processed: 61155



CSRS-PPP Usage Statistics

- NRCan has processed over **3.8 million** GNSS data sets with the CSRS-PPP service since 2003
- **2018 Usage Statistics**
  - 6605 unique users
  - Almost 600,000 data sets processed
  - 78% static, 22% kinematic
  - 98.7% dual frequency
  - 23% NAD83(CSRS) (21% in 2017), 77% ITRF
  - 20% CGVD2013 **(12% in 2017)**, 80% CGVD28 (% of NAD83 solutions)
- Note: **2016 user survey** respondents reported satisfaction with CSRS-PPP service but some requested support for new GNSS satellite constellations and RINEX v3

CSRS-PPP – 2018 Software Transition

CSRS-PPP – 2018 Software Transition

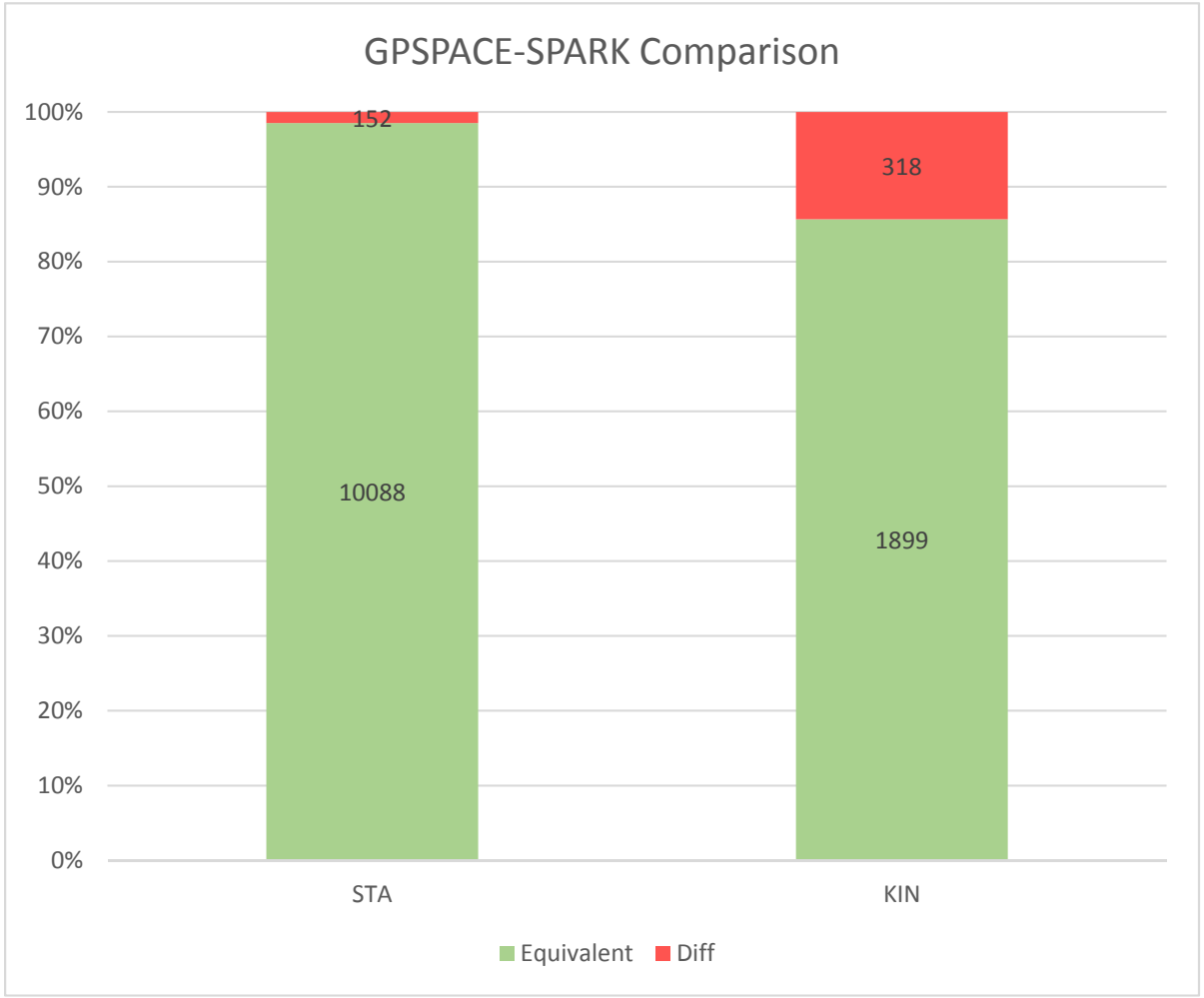
Why did CGS transition to SPARK?

- Modern processing engine
  - Capable of handling all constellations and signals
  - Supports RINEX v3
  - Single frequency code + phase solution
  - Pathway to PPP-AR and co-operative PPP (faster convergence = shorter observation requirements)
- Completely updated pre/post-processing modules
  - Easier to maintain
    - Perl script replaced with modular Python and Java tools
    - RINEX validation includes support for RINEX v3
    - Post-processing uses common transformation libraries (GPS-H/TRX)

CSRS-PPP – 2018 Software Transition

How did SPARK and GPSPACE results compare?

- Comparison of 13,459 submissions (2018-04-10 to 2018-04-24)



Solutions were flagged for further analysis if:

Static: 3D-diff > 3D standard deviation at 95%

Kinematic: RMS of vert. diffs > 5 cm

CSRS-PPP – SPARK Accuracy Analysis

DATA

- **1000** 24h-observation RINEX files (sampling rate – 30s)
  - 20 stations from CACS: 15 National - 4 WCDA -1 Regional
  - 52 days between January 6th and December 28th, 2016
- Reference positions: weekly IGS estimated pos. (SSC file)

ALBH	Victoria/Sidney -	WCDA
ALGO	Algonquin -	CSRS
BAKE	Baker Lake -	CSRS
CHUR	Churchill -	CSRS
DRAO	Penticton -	WCDA
DUBO	Lac du Bonnet -	CSRS
FLIN	Flin Flon -	CSRS
FRDN	Fredericton -	CSRS
HLFX	Halifax -	CSRS
IQAL	Iqualuit -	CSRS
KUUJ	Kuujjuarapik -	CSRS
NANO	Nanoose -	WCDA
NRC1	Ottawa -	CSRS
PRDS	Calgary -	CSRS
SASK	Saskatoon -	CSRS
SCH2	Schefferville -	CSRS
VALD	Val d'Or -	REGIO
WHIT	Whitehorse -	CSRS
WILL	Williams lake -	WCDA
YELL	Yellowknife -	CSRS

Process Parameters

- Mode: Static & Kinematic
- GNSS: GPS only & GPS + GLONASS
- Frequency: L1 + L2
- Orbits and Clocks: IGS products (finals)
- Pole tide corrections (erp)
- Tropospheric Zenith Delay (TZD)
- Cut-off elevation: 7.5
- Ant/sat offsets: ATX/SVB files
- Tropospheric gradient estimation
- Ocean Loading OTL

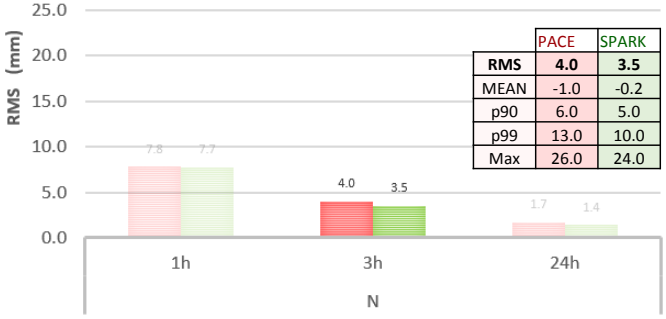
* GPSPACE version1.05 11216 ------ SPARK version 2.1.0 (r421)

* Data processed on RTOPSDATA2 between April 9th and April 14th, 2018

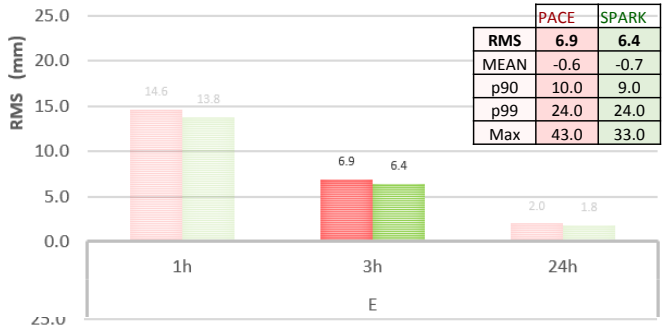
CSRS-PPP – SPARK Accuracy Analysis

Results

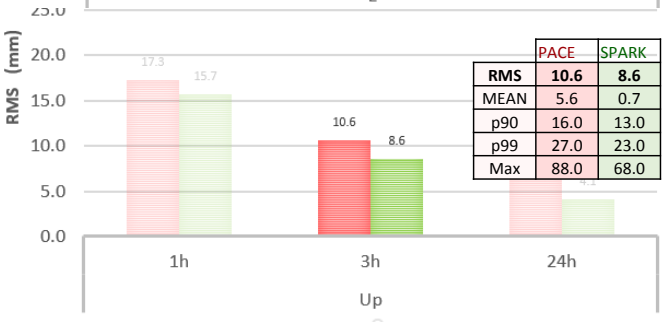
Static - GPS + GLONASS



	PACE	SPARK
RMS	**4.0**	**3.5**
MEAN	-1.0	-0.2
p90	6.0	5.0
p99	13.0	10.0
Max	26.0	24.0

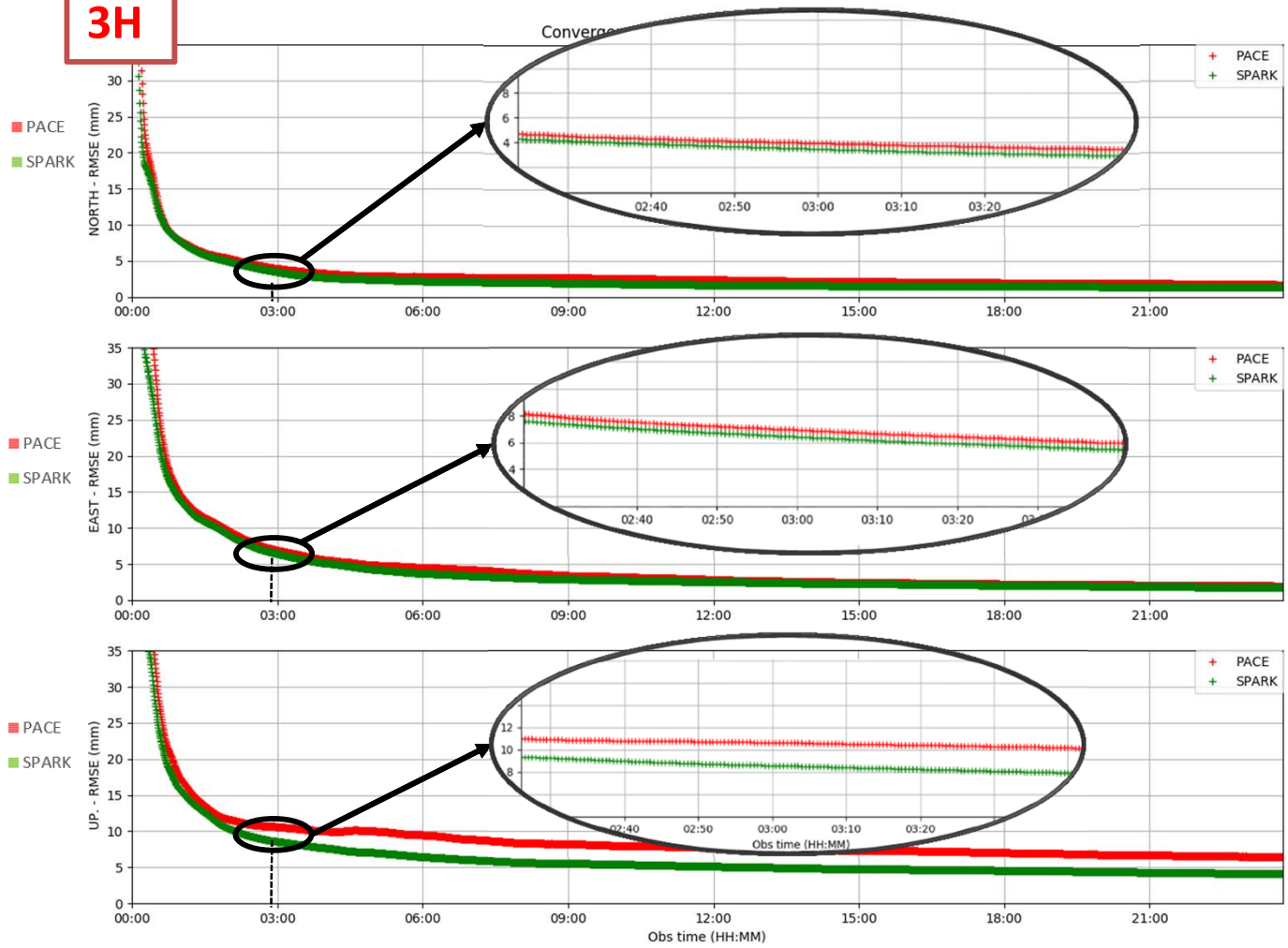


	PACE	SPARK
RMS	**6.9**	**6.4**
MEAN	-0.6	-0.7
p90	10.0	9.0
p99	24.0	24.0
Max	43.0	33.0



	PACE	SPARK
RMS	**10.6**	**8.6**
MEAN	5.6	0.7
p90	16.0	13.0
p99	27.0	23.0
Max	88.0	68.0

3H

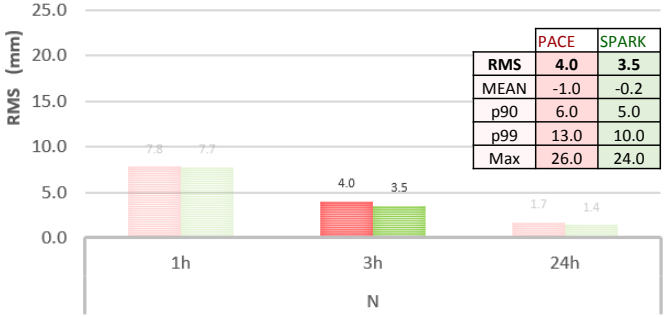


CSRS-PPP – SPARK Accuracy Analysis

Results

Static - GPS + GLONASS

3H



	PACE	SPARK
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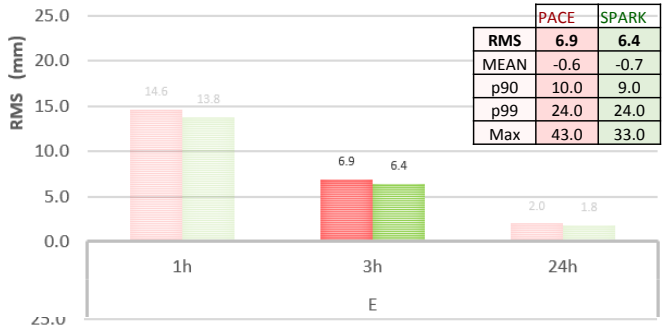
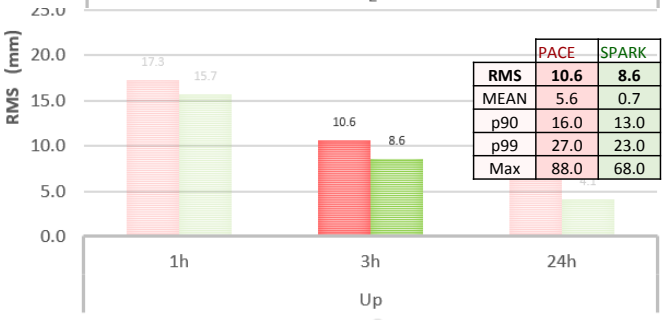
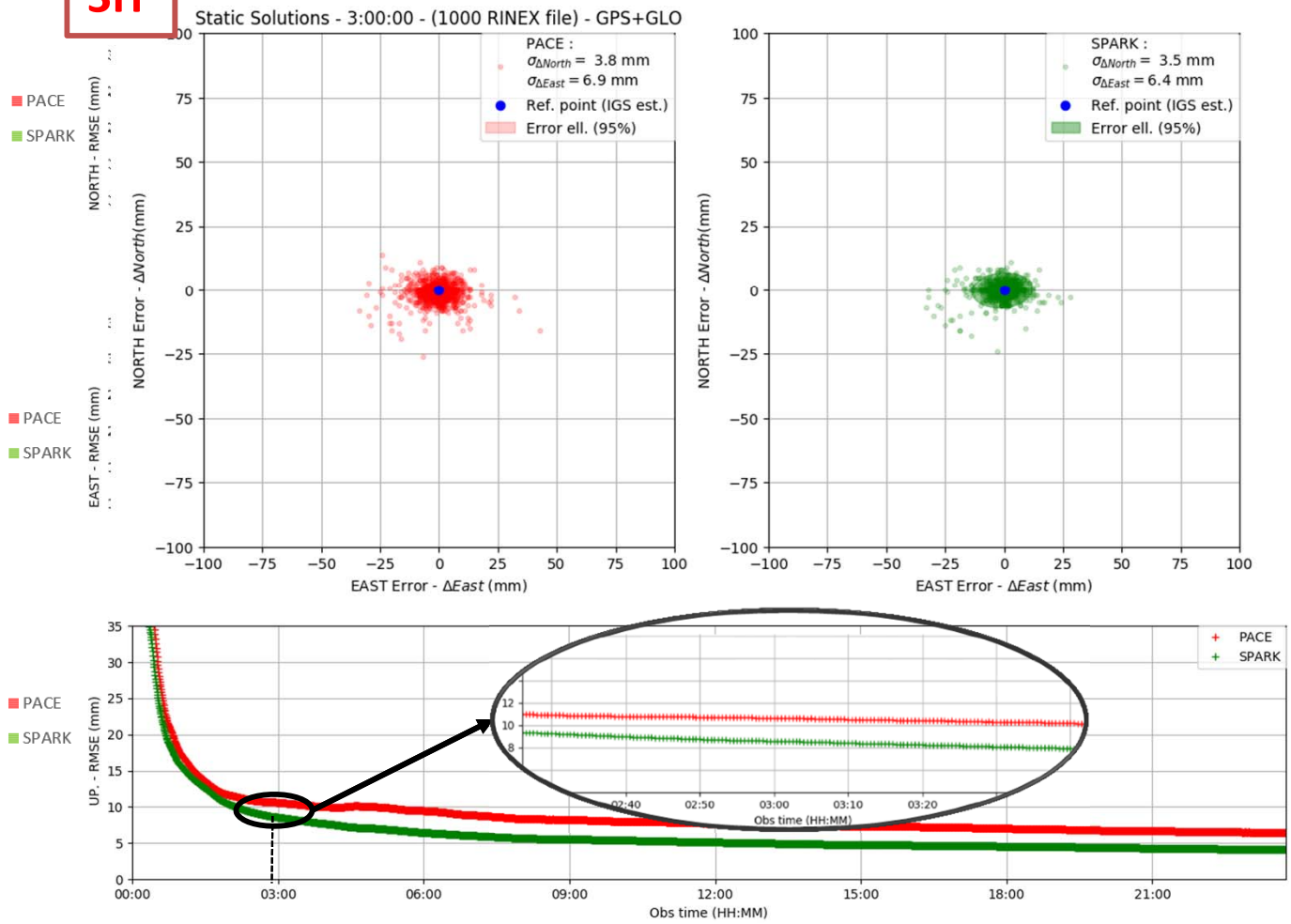
MEAN	-1.0	-0.2
p90	6.0	5.0
p99	13.0	10.0
Max	26.0	24.0



	PACE	SPARK
RMS	**6.9**	**6.4**
MEAN	-0.6	-0.7
p90	10.0	9.0
p99	24.0	24.0
Max	43.0	33.0



	PACE	SPARK
RMS	**10.6**	**8.6**
MEAN	5.6	0.7
p90	16.0	13.0
p99	27.0	23.0
Max	88.0	68.0

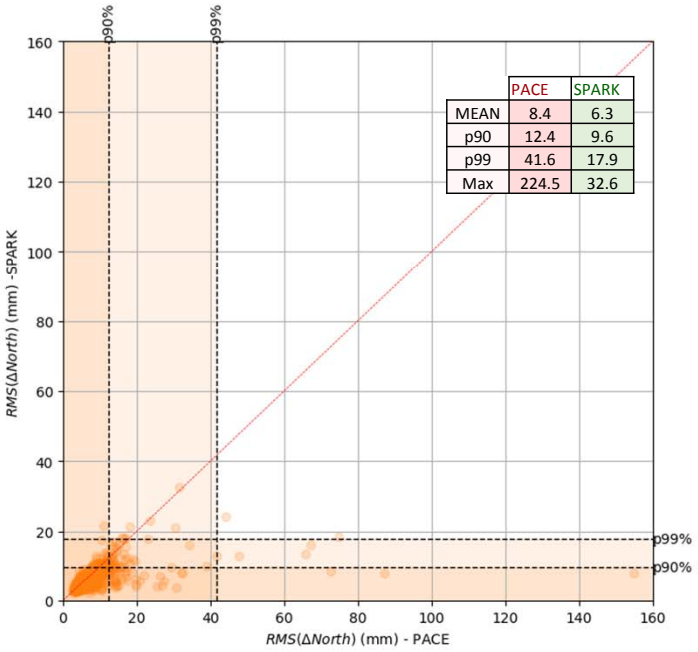


CSRS-PPP – SPARK Accuracy Analysis

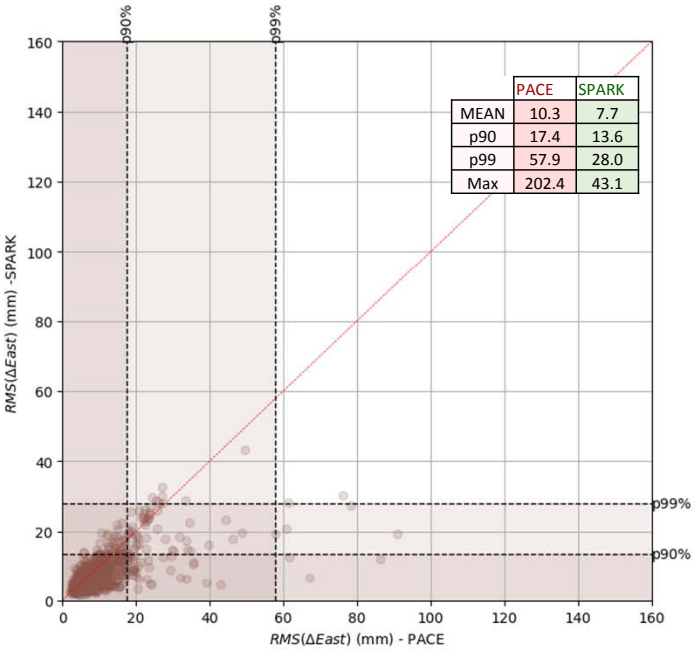
Results

Kinematic – GPS + GLONASS – Obs. time: 3h

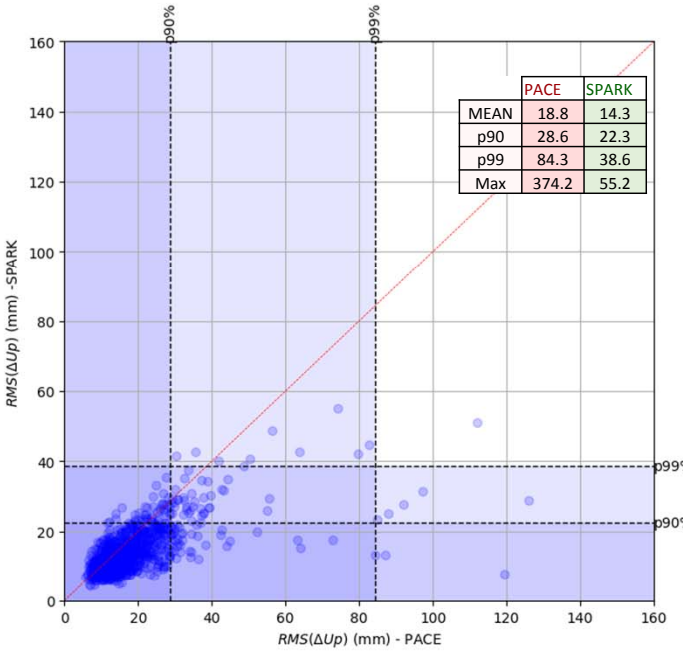
RMS of estimated positions over all epochs



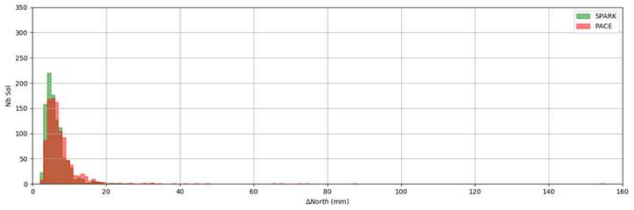
	PACE	SPARK
MEAN	8.4	6.3
p90	12.4	9.6
p99	41.6	17.9
Max	224.5	32.6

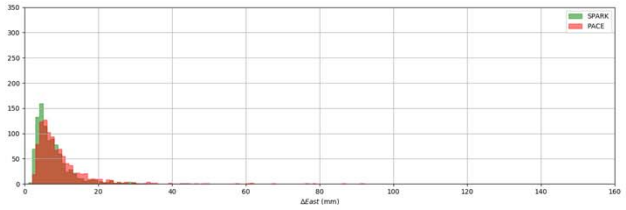


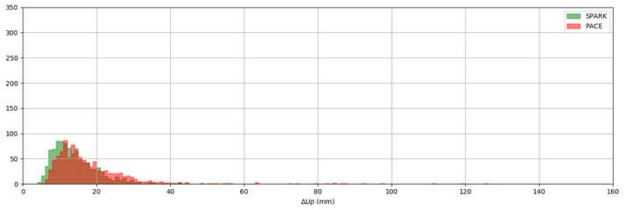
	PACE	SPARK
MEAN	10.3	7.7
p90	17.4	13.6
p99	57.9	28.0
Max	202.4	43.1



	PACE	SPARK
MEAN	18.8	14.3
p90	28.6	22.3
p99	84.3	38.6
Max	374.2	55.2







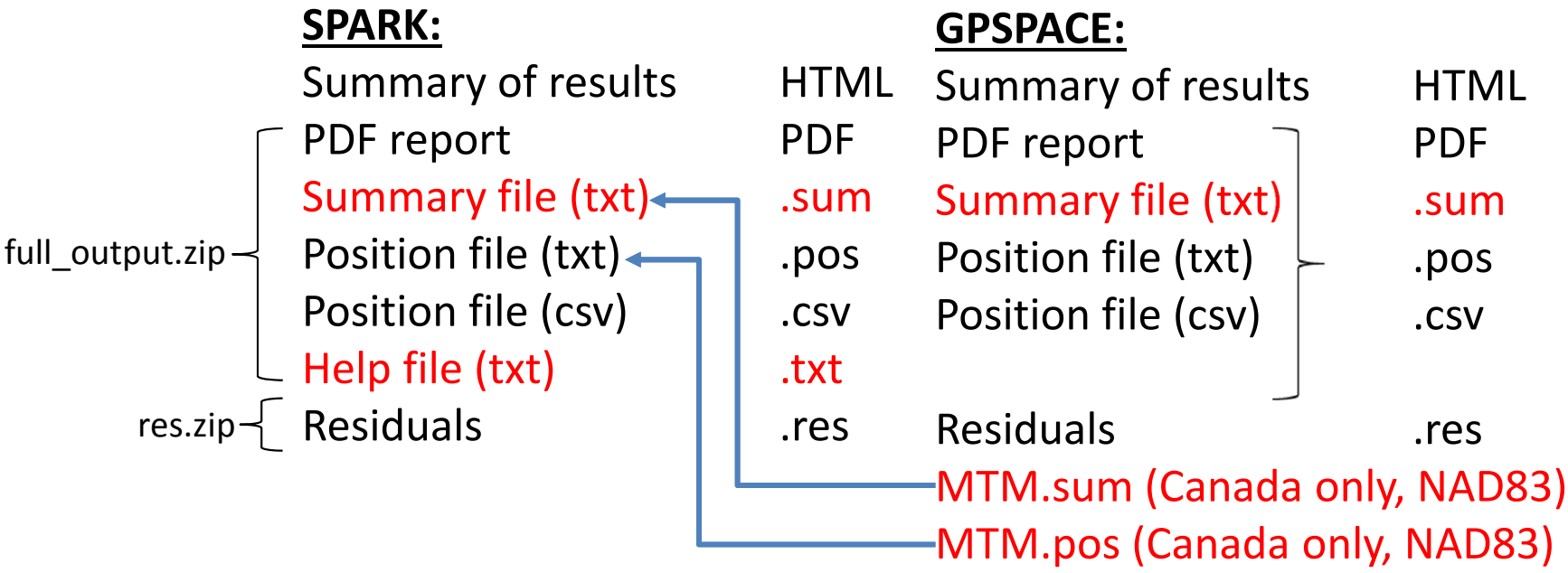
CSRS-PPP – SPARK Accuracy Analysis

- **Accuracy Analysis Conclusions**
  - Validated accuracy of new CSRS-PPP engine
    - SPARK 24h static solutions were within 2mm horizontal and 4mm vertical of truth
  - Confirmed equal or better quality SPARK vs. GPSPACE
    - Horizontal equivalent (< 1 mm)
    - Vertical 4-5 mm bias in GPSPACE
    - 20 - 30% improvement in kinematic solutions with SPARK

CSRS-PPP – 2018 Software Transition

What was the impact on users?

- Some outputs changed
  - Summary file (.sum) was the most significant change
  - MTM outputs for Canadian NAD83 solutions are now merged directly into original .sum and .pos files



CSRS-PPP – 2018 Software Transition

SPARK summary text file (.sum)

```
HDR GRP CANADIAN GEODETIC SURVEY, SURVEYOR GENERAL BRANCH, NATURAL RESOURCES CANADA
HDR ADR GOVERNMENT OF CANADA, 588 BOOTH STREET ROOM 334, OTTAWA ONTARIO K1A 0Y7
HDR TEL 343-292-6617
HDR FAX 613-996-9843
HDR EMA nrcan.geodeticinformationservices.rncan@canada.ca
VER 2.1.0 (2018-05-23 r440)
NOW 2018-06-11 17:44:58.00
RNX yell1210.18o
MOD STATIC
BEG 2018-05-01 00:00:00.00
END 2018-05-01 23:59:30.00
INT 30.00
EPO 2880 2880 2880

SP3 igs19992.sp3
SP3 igs19993.sp3
CLK igs19992.clk
CLK igs19993.clk
ERP igs19997.erp
ATX gpsppp.pcv_absolute_igs14
ELV 7.5
TZD GPT
REC JAVAD TRE_3N DELTA
ANT AOAD/M_T         NONE
ARP     0.000     0.000     0.100
PCO G01    0.001 -0.001  0.092
PCO G02   -0.000 -0.001  0.120
PCO R01    0.001 -0.001  0.092
PCO R02   -0.000 -0.001  0.120
```

3-character codes

CSRS-PPP – 2018 Software Transition

SPARK summary text file (.sum)

```
POS CRD  SYST         EPOCH           APRIORI          ESTIMATED       DIFF SIGMA(95%) CORRELATIONS
POS   X IGS14 18:121:43185     -1224451.8900     -1224452.9400    -1.0500     0.0040  1.0000
POS   Y IGS14 18:121:43185     -2689217.2800     -2689216.2000     1.0800     0.0047  0.1677  1.0000
POS   Z IGS14 18:121:43185      5633638.0900      5633638.2849     0.1949     0.0074 -0.3978 -0.7513  1.0000
POS LAT IGS14 18:121:43185    62 28 51.19452    62 28 51.21312     0.5759     0.0026  1.0000
POS LON IGS14 18:121:43185  -114 28 50.44340  -114 28 50.54135    -1.4031     0.0038 -0.0047  1.0000
POS HGT IGS14 18:121:43185           181.0668          180.9865    -0.0803     0.0084 -0.1580 -0.0003  1.0000
POS   X NAD83 10:001:00000     -1224495.5544     -1224496.6049    -1.0505     0.0040  1.0000
POS   Y NAD83 10:001:00000     -2689220.6170     -2689219.5357     1.0813     0.0047  0.1677  1.0000
POS   Z NAD83 10:001:00000      5633630.8514      5633631.0448     0.1934     0.0074 -0.3978 -0.7513  1.0000
POS LAT NAD83 10:001:00000    62 28 50.48119    62 28 50.49980     0.5760     0.0026  1.0000
POS LON NAD83 10:001:00000  -114 28 53.12085  -114 28 53.21887    -1.4041     0.0038 -0.0047  1.0000
POS HGT NAD83 10:001:00000           184.4107          184.3288    -0.0819     0.0084 -0.1580 -0.0003  1.0000
PRJ TYPE ZONE    EASTING     NORTHING SCALE_POINT SCALE_COMBINED
PRJ  UTM   11 629807.830  6930262.617    0.999806       0.999778
PRJ  MTM   23 279973.889  6929903.510    0.999908       0.999879
OHT     SYST    MODEL  HEIGHT
OHT CGVD2013 CGG2013a 210.928
VLM NAD83v6VG
OFF -418899.2123 0.2409 ns
DRI -1236.6557 ns/day
RES G C1W 0.379
RES G C2W 0.390
RES G L1W 0.002
RES G L2W 0.001
RES R CIF 1.156
RES R LIF 0.007
```

POS – positions (including reference system, epoch, a priori, estimate, and sigma)

OHT – orthometric height

PRJ – projected coordinates for UTM and MTM

CSRS-PPP – 2018 Software Transition

- **User Impact Summary**
  - Improvement of 4-5 mm in height
  - No differences to submission applications
  - Some outputs slightly changed (e.g. PDF report)
  - Summary text file (.sum) completely updated with 3-character codes
  - Residual file format switched from text to JSON
    - Script available to convert JSON residuals to former text format

CSRS-PPP Solution Validation

- "Calibrate" your GPS equipment with PPP in static mode over known points
- Review information in reports (.pdf and .sum)
  - Check percentage of data rejected
  - Verify antenna information
  - Check the satellite coverage
  - Check stability of tropospheric correction
  - Check observation residuals
  - Verify reference frame, epoch, and vertical datum (if applicable)
- Ensure tracking long enough for convergence
- Multiple occupation
- Compare to other online positioning services (e.g. AUSPOS)
  - https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos

CSRS-PPP Outputs (PDF report)

CSRS-PPP 2.26.0 (2019-02-25)

drao0720.19o
DRAO CACS-GSD 887006 Penticton BC Canada

Data Start	Data End	Duration of Observations
2019-03-13 00:00:00.00	2019-03-13 23:59:30.00	23:59:30
Processing Time		Product Type: NRCan Ultra-rapid
22:54:43 UTC 2019/03/14		
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	Rejected Epochs: 0.00 %	**Estimation Steps**
7.5 degrees		30.00 sec
Antenna Model: TRM59800.00 SCIS	**APC to ARP**	**ARP to Marker**
	L1 = 0.087 m L2 = 0.116 m	H:0.100m / E:0.000m / N:0.000m

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

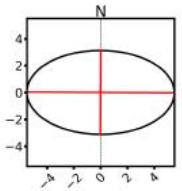
Estimated Position for drao0720.19o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)†	49° 19' 21.40972"	-119° 37' 29.87651"	542.220 m
Sigmas(95%)	0.003 m	0.004 m	0.009 m
A priori*	49° 19' 21.41016"	-119° 37' 29.87542"	542.224 m
Estimated – A priori	-0.014 m	-0.022 m	-0.005 m

Orthometric Height CGVD2013 (CGG2013a)

558.544 m
(click for height reference information)

95% Error Ellipse (mm)
semi-major: 5.495 mm
semi-minor: 3.122 mm
semi-major azimuth: 90° 17' 46.43"



UTM (North) Zone 11

5466635.021 m (N)
309256.449 m (E)

Scale Factors
1.000047 (point)
0.999962 (combined)

*(Coordinates from RINEX header used as a priori position)

†(Epoch transformation using velocity grid NAD83v70VG)

Product Type
NRCan Ultra-rapid

Rejected Epochs
0.00 %

Antenna Model
TRM59800.00 SCIS

CSRS-PPP Outputs (PDF report)

CSRS-PPP 2.26.0 (2019-02-25)

drao0720.19o
DRAO CACS-GSD 887006 Penticton BC Canada

Data Start	Data End	Duration of Observations
2019-03-13 00:00:00.00	2019-03-13 23:59:30.00	23:59:30
Processing Time		**Product Type**
22:54:43 UTC 2019/03/14		NRCan Ultra-rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs**	**Estimation Steps**
7.5 degrees	0.00 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRM59800.00 SCIS	L1 = 0.087 m L2 = 0.116 m	H:0.100m / E:0.000m / N:0.000m

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

Estimated Position for drao0720.19o

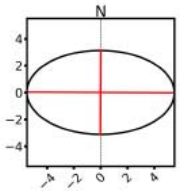
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)†	49° 19' 21.40972"	-119° 37' 29.87651"	542.220 m
Sigmas(95%)	0.003 m	0.004 m	0.009 m
A priori*	49° 19' 21.41016"	-119° 37' 29.87542"	542.224 m
Estimated – A priori	-0.014 m	-0.022 m	-0.005 m

Orthometric Height CGVD2013 (CGG2013a)

558.544 m

(click for height reference information)

95% Error Ellipse (mm)
semi-major: 5.495 mm
semi-minor: 3.122 mm
semi-major azimuth: 90° 17' 46.43"



UTM (North) Zone 11

5466635.021 m (N)
309256.449 m (E)

Scale Factors
1.000047 (point)
0.999962 (combined)

*(Coordinates from RINEX header used as a priori position)
†(Epoch transformation using velocity grid NAD83v70VG)

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) 2002†	49° 19' 21.40972"	-119 ° 37' 29.87651"	542.220 m
Sigmas(95%)	0.003 m	0.004 m	0.009 m

Orthometric Height CGVD2013 (CGG2013a)

558.544 m

(click for height reference information)

*(Coordinates from RINEX header used as a priori position)
†(Epoch transformation using velocity grid NAD83v70VG)

CSRS-PPP Solution Validation

What can cause solution differences?

POS	CRD	SYST	EPOCH	A_PRIORI	ESTIMATED	DIFF	SIGMA(95%)
POS	X	NAD83	02:001:00000	-2059164.0600	-2059164.0827	-0.0227	0.0049
POS	Y	NAD83	02:001:00000	-3621109.5700	-3621109.5654	0.0046	0.0057
POS	Z	NAD83	02:001:00000	4814432.2300	4814432.2173	-0.0127	0.0065
POS	LAT	NAD83	02:001:00000	49 19 21.41016	49 19 21.40972	-0.0137	0.0025
POS	LON	NAD83	02:001:00000	-119 37 29.87542	-119 37 29.87651	-0.0219	0.0044
POS	HGT	NAD83	02:001:00000	542.2241	542.2196	-0.0048	0.0085

PRJ	TYPE	ZONE	EASTING	NORTHING	SCALE_POINT	SCALE_COMBINED	HEMISPHERE
PRJ	UTM	11	309256.449	5466635.021	1.000047	0.999962	N
PRJ	MTM	25	332061.502	5465027.552	0.999909	0.999824	

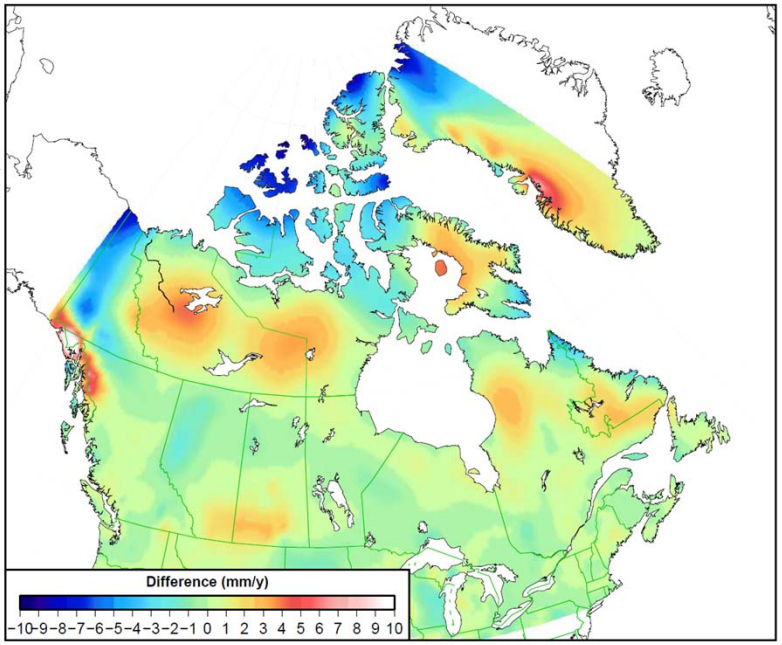
OHT	SYST	MODEL	HEIGHT
OHT	CGVD2013	CGG2013a	558.5442

VLM NAD83v70VG

Verify reference system and epoch match requirements

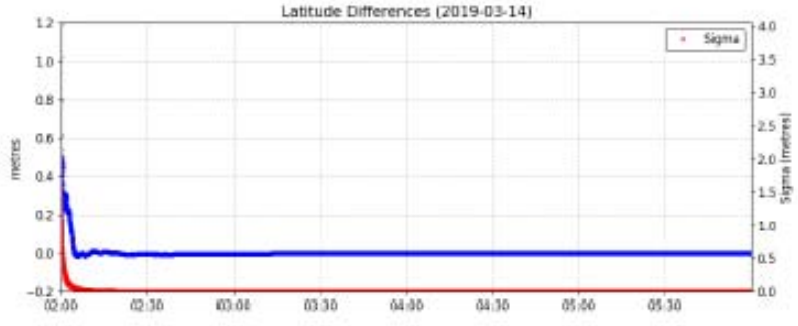
If working with orthometric heights, note datum and model

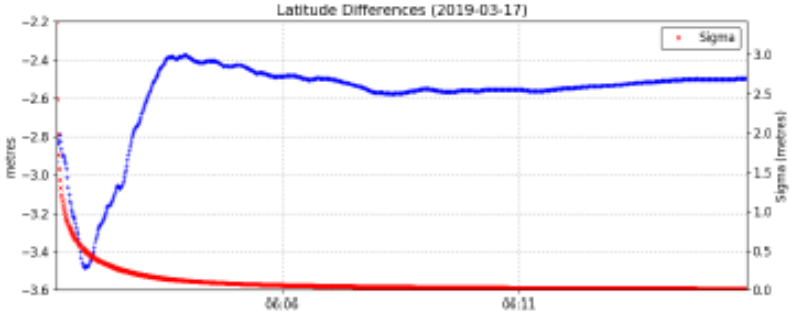
Important to note velocity model when working with older epochs of NAD83

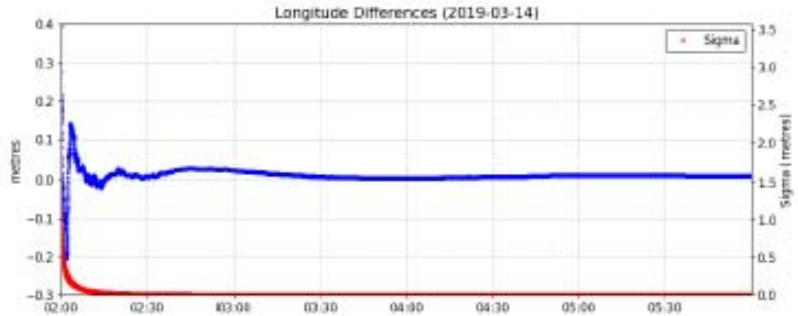


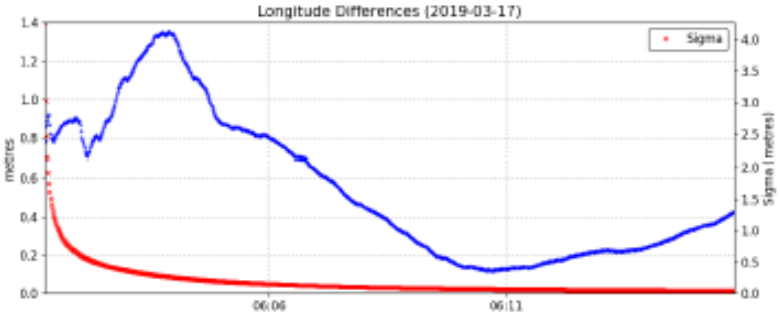
Vertical difference between v7 and v6 velocity grids

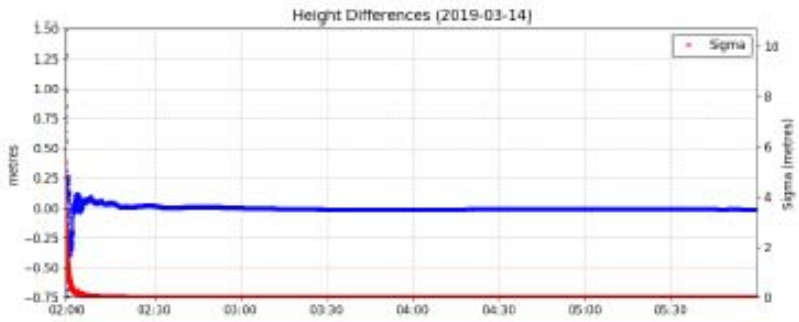
CSRS-PPP Solution Validation – Convergence

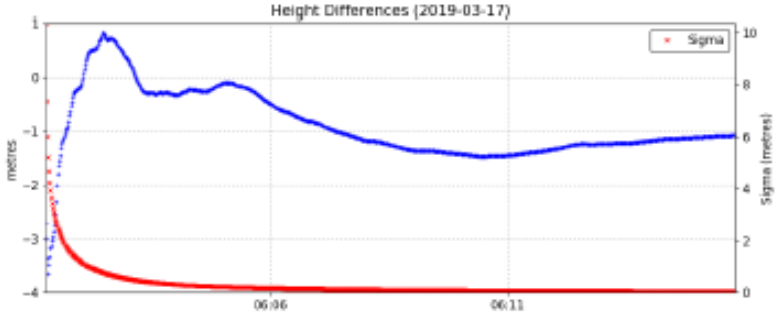












CSRS-PPP Future Plans

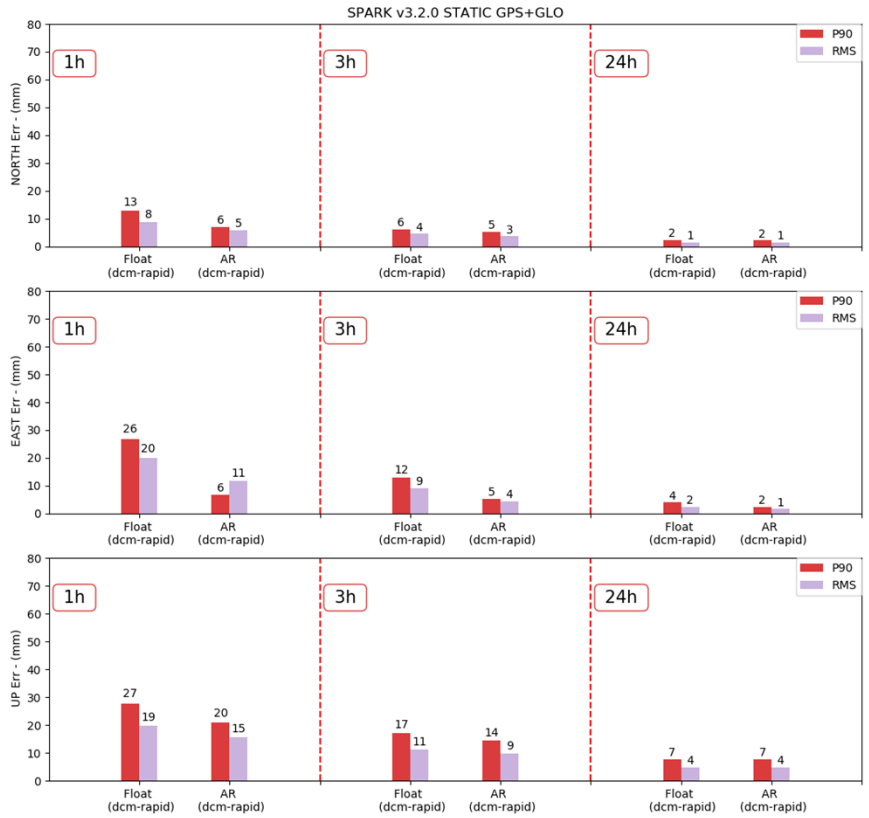
Towards PPP-AR

- The next major update (SPARK v3) will include ambiguity resolution (PPP-AR)

- Expected benefits include:
  - Higher accuracy for short observation sessions (1-2 hours)
  - Improved longitude estimates for 24-hour static sessions
  - Improved receiver clock and atmospheric delay estimates

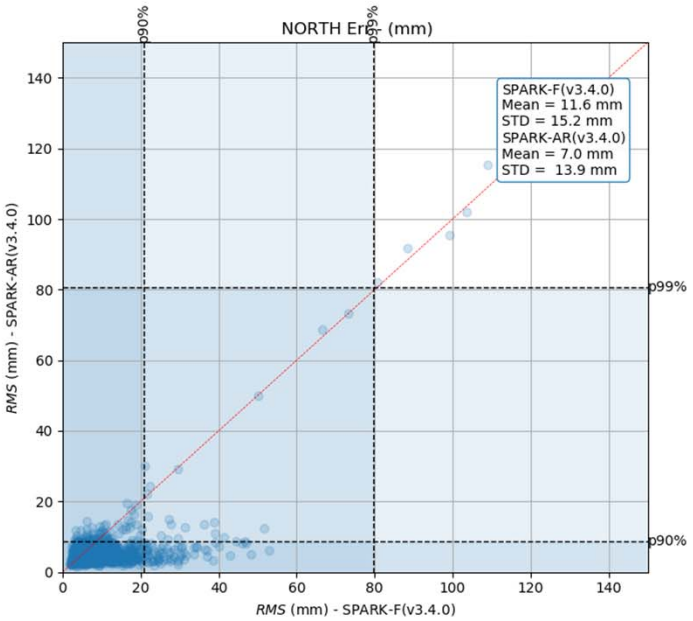
Towards PPP-AR

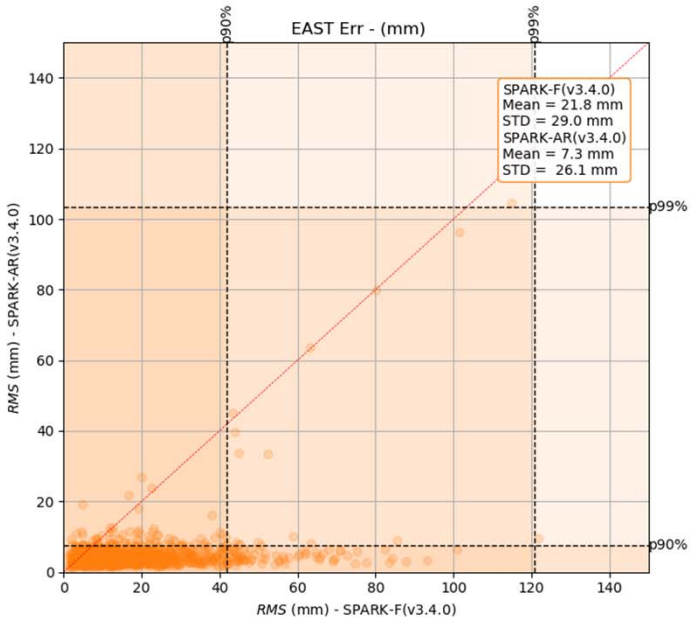
- Statistics based on 1000 solutions over 52 weeks in 2018
- Static solutions
- GPS + GLONASS
- Ambiguity resolution for GPS only

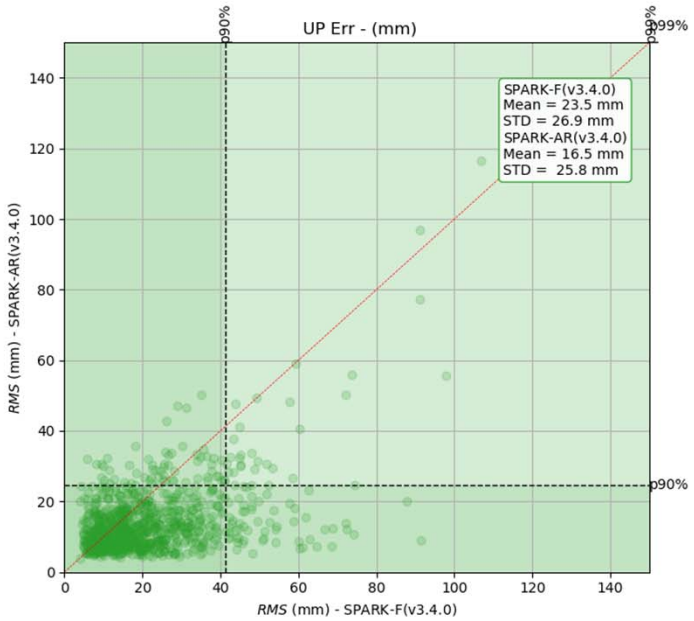


Towards PPP-AR

- 1-hour kinematic solutions, GPS+GLONASS







Towards PPP-AR

- The main challenge to offering a PPP-AR service is the availability of products
- Our current product flow relies heavily on IGS products:

Orbit and Clock Products	Usage (2018)
NRCan Hourly	8%
NRCan Rapid	34%
IGS Final	52%
IGS Final (repro1)	6%

- But the IGS does not provide products for PPP-AR

Towards PPP-AR

- The strategy currently planned is:
  - **Ultra-rapid** and **Rapid** products enable PPP-AR (NRCan solutions)
  - **Final** products:
    - NRCan has initiated a new IGS working group on PPP-AR (Nov 2018)
    - Before the IGS officially delivers combined PPP-AR products, we will be computing our own IGS-like combination enabling PPP-AR

CSRS-PPP v3 Report Updates

SPARK

CSRS-PPP 2.26.0 (2019-02-25)

drao0720.19o
DRAO CACS-GSD 887006 Penticton BC Canada

Data Start	Data End	Duration of Observations
2019-03-13 00:00:00.00	2019-03-13 23:59:30.00	23:59:30
Processing Time		**Product Type**
22:54:43 UTC 2019/03/14		NRCan Ultra-rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs**	**Estimation Steps**
7.5 degrees	0.00 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRM59800.00 SCIS	L1 = 0.087 m L2 = 0.116 m	H:0.100m / E:0.000m / N:0.000m

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

Estimated Position for drao0720.19o

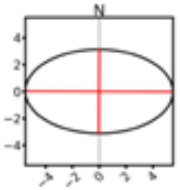
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)†	49° 19' 21.40972"	-119° 37' 29.87651"	542.220 m
Sigmas(95%)	0.003 m	0.004 m	0.009 m
A priori*	49° 19' 21.41016"	-119° 37' 29.87542"	542.224 m
Estimated – A priori	-0.014 m	-0.022 m	-0.005 m

Orthometric Height CGVD2013 (CGG2013a)

558.544 m

(click for height reference information)

95% Error Ellipse (mm)
semi-major: 5.495 mm
semi-minor: 3.122 mm
semi-major azimuth: 90° 17' 46.43"



UTM (North) Zone 11

5466635.021 m (N)
309256.449 m (E)

Scale Factors
1.000047 (point)
0.999962 (combined)

*(Coordinates from RINEX header used as a priori position)

†(Epoch transformation using velocity grid NAD83v70VG)

SPARK + AR

CSRS-PPP 2.26.0/3.4.0 (2019-03-01)

drao0720.19o
DRAO CACS-GSD 887006 Penticton BC Canada

Data Start	Data End	Duration of Observations
2019-03-13 00:00:00.00	2019-03-13 23:59:30.00	23:59:30
Processing Time		**Product Type**
14:50:28 UTC 2019/03/15		NRCan Rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs** / **Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 % / 88.61 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TRM59800.00 SCIS	L1 = 0.087 m L2 = 0.116 m	H:0.100m / E:0.000m / N:0.000m

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

Estimated Position for drao0720.19o

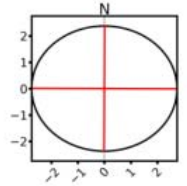
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002)†	49° 19' 21.40974"	-119° 37' 29.87648"	542.222 m
Sigmas(95%)	0.002 m	0.002 m	0.007 m
A priori*	49° 19' 21.41016"	-119° 37' 29.87542"	542.224 m
Estimated – A priori	-0.013 m	-0.021 m	-0.002 m

Orthometric Height CGVD2013 (CGG2013a)

558.547 m

(click for height reference information)

95% Error Ellipse (mm)
semi-major: 2.747 mm
semi-minor: 2.373 mm
semi-major azimuth: 90° 13' 57.19"



UTM (North) Zone 11

5466635.022 m (N)
309256.449 m (E)

Scale Factors
1.000047 (point)
0.999962 (combined)

*(Coordinates from RINEX header used as a priori position)

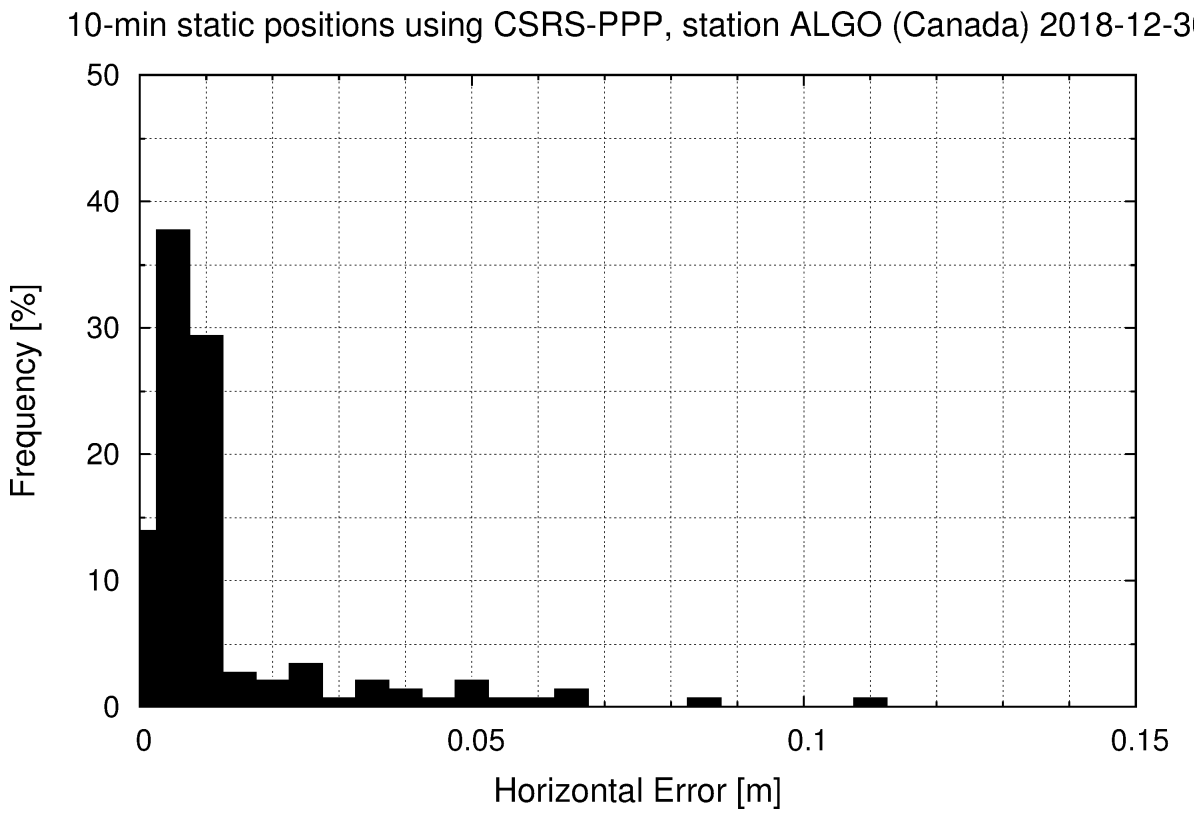
†(Epoch transformation using velocity grid NAD83v70VG)

What about multi-GNSS?

- Challenge #1: product availability
  - No multi-GNSS combined products from the IGS
  - We now have access to NASA JPL's Gipsy-X software but we need to learn how to use it, assess solution quality and automate solutions
- Challenge #2: antenna calibrations
  - Multi-GNSS is great for converging to cm-level accuracies
  - But the current lack of antenna calibrations impacts mm-level accuracies
  - IGS actively working on this issue
- Target date: 2021

What about multi-GNSS?

- SPARK is ready!
- Example:
  - Station ALGO
  - GPS (L1/L2/L5) + AR
  - GLONASS (L1/L2)
  - Galileo (L1/L5) + AR
  - 24 hours divided into 10-min sessions
  - Products from CNES



CSRS-PPP – Summary

- Service was launched in 2003 and has now processed over 3.8 million RINEX files
- In August 2018 the service was upgraded with a new modern processing engine (SPARK v2)
- NRCan is planning to upgrade to SPARK v3 with support for PPP-AR in 2019
- CSRS-PPP has proven to be an efficient means to access the NAD83(CSRS) reference frame, but it is important that users understand and validate their results
- Multi-GNSS – Target date 2021 (Same as USA)

Acknowledgements

CSRS-PPP Team

Simon Banville

Brian Donahue

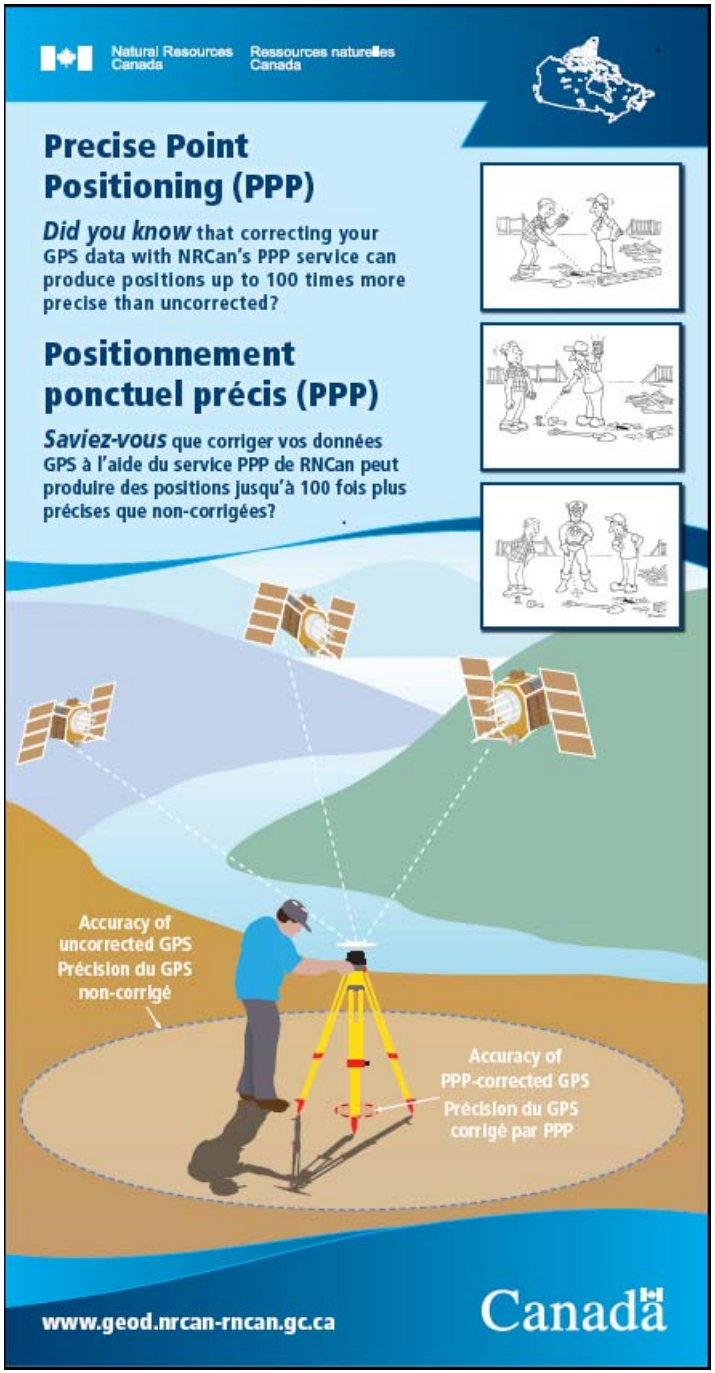
Justin Farinaccio

Elyes Hassen

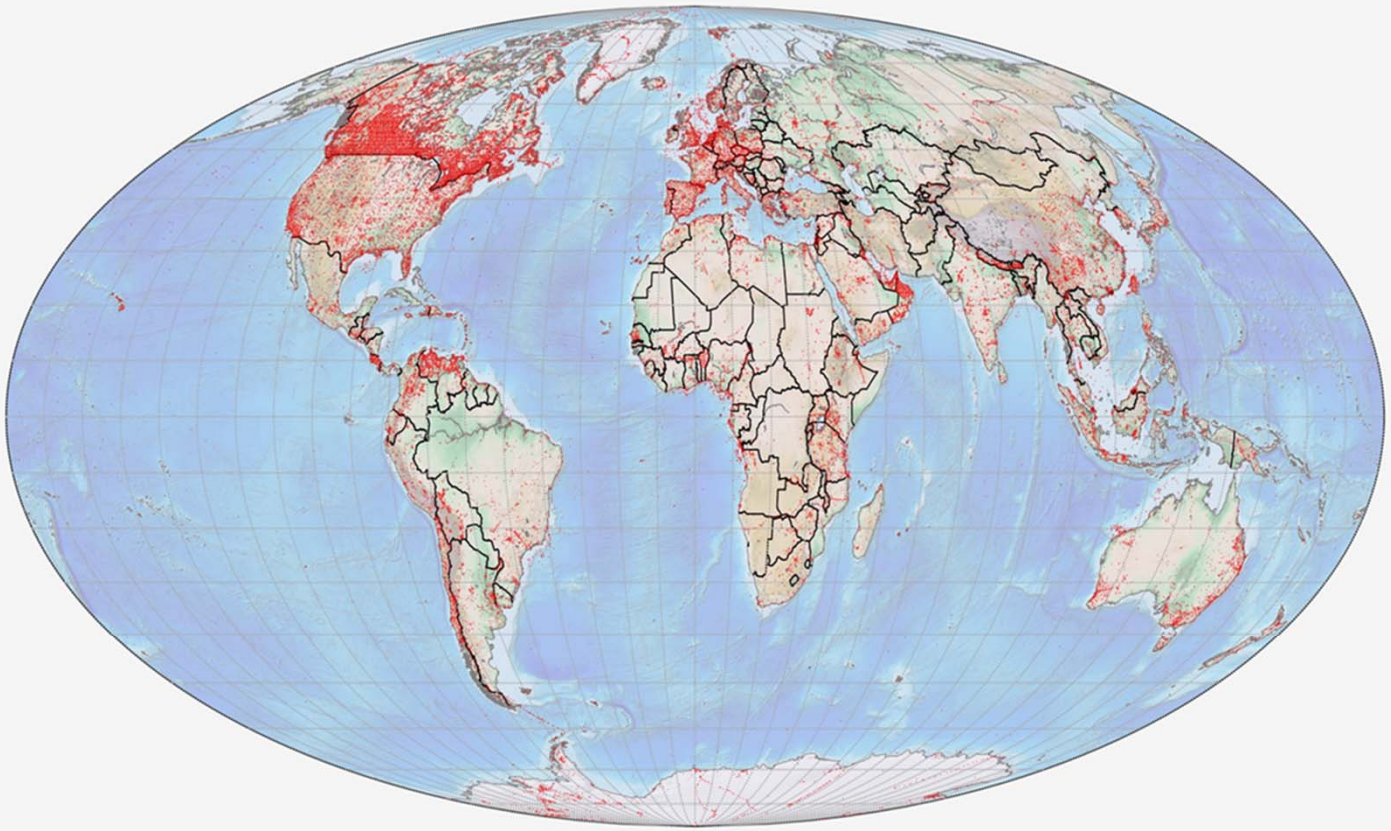
Omid Kamali

Questions?

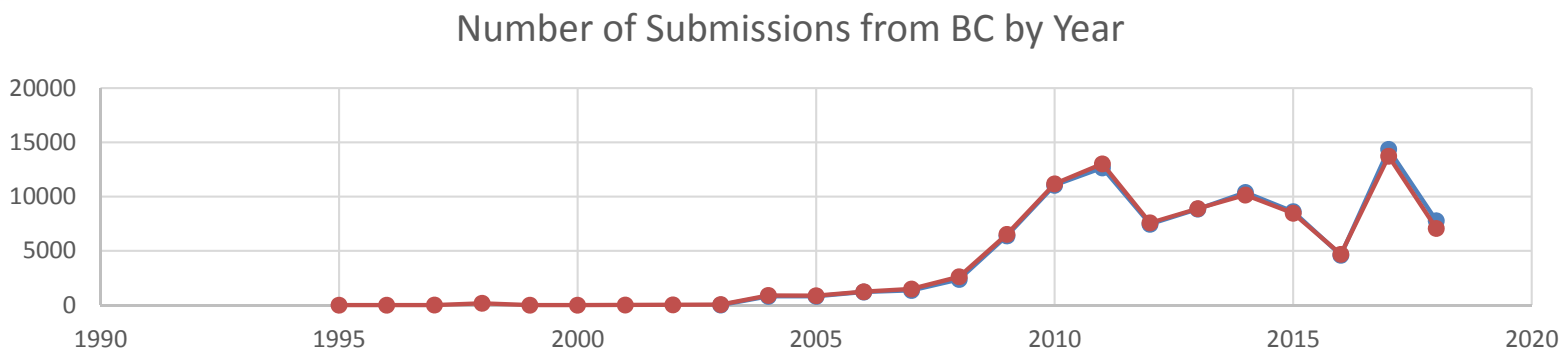
General information
Website: webapp.geod.nrcan.gc.ca
Email: nrcan.geodeticinformationservices.rncan@canada.ca

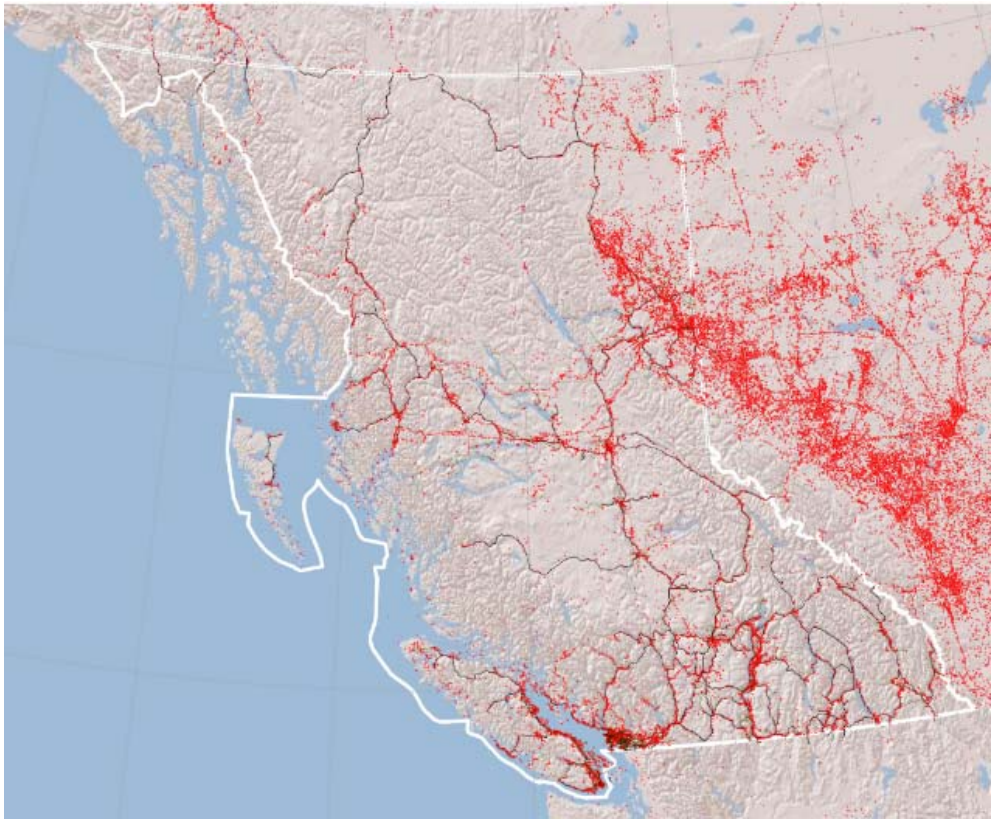


CSRS-PPP Global Usage 2003-2015



CSRS-PPP BC Usage



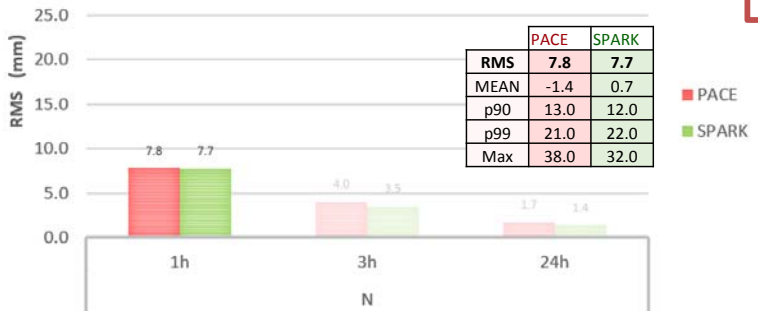


CSRS-PPP – SPARK Accuracy Analysis

Results

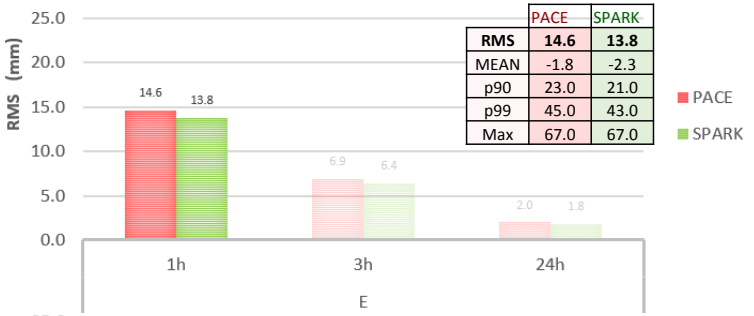
Static - GPS + GLONASS

1H



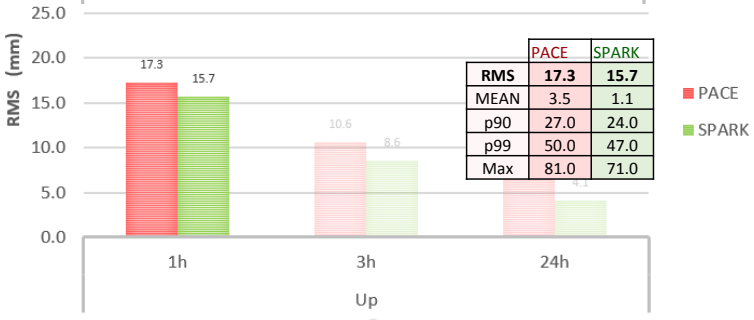
	PACE	SPARK
RMS	**7.8**	**7.7**
MEAN	-1.4	0.7
p90	13.0	12.0
p99	21.0	22.0
Max	38.0	32.0

PACE
SPARK



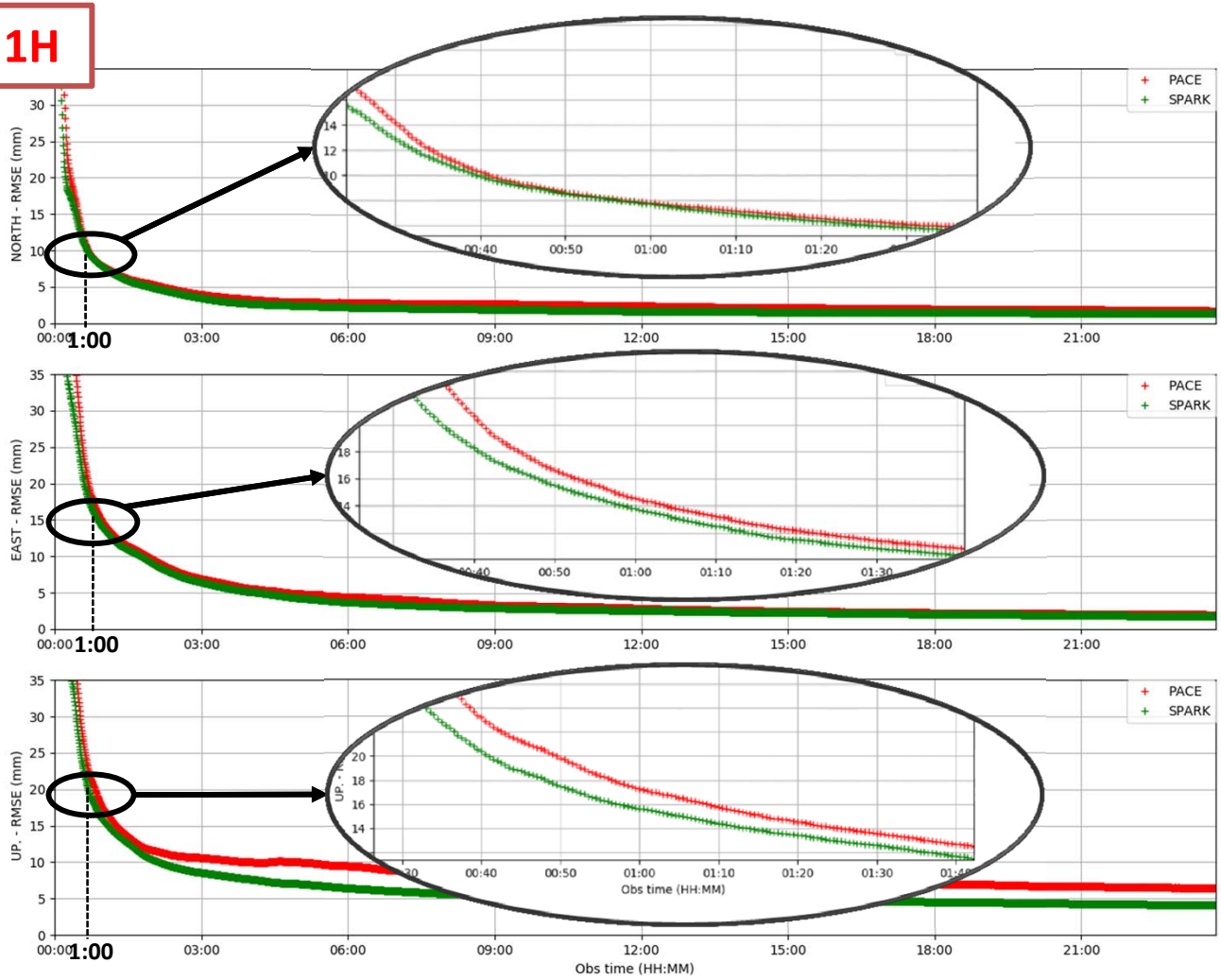
	PACE	SPARK
RMS	**14.6**	**13.8**
MEAN	-1.8	-2.3
p90	23.0	21.0
p99	45.0	43.0
Max	67.0	67.0

PACE
SPARK



	PACE	SPARK
RMS	**17.3**	**15.7**
MEAN	3.5	1.1
p90	27.0	24.0
p99	50.0	47.0
Max	81.0	71.0

PACE
SPARK

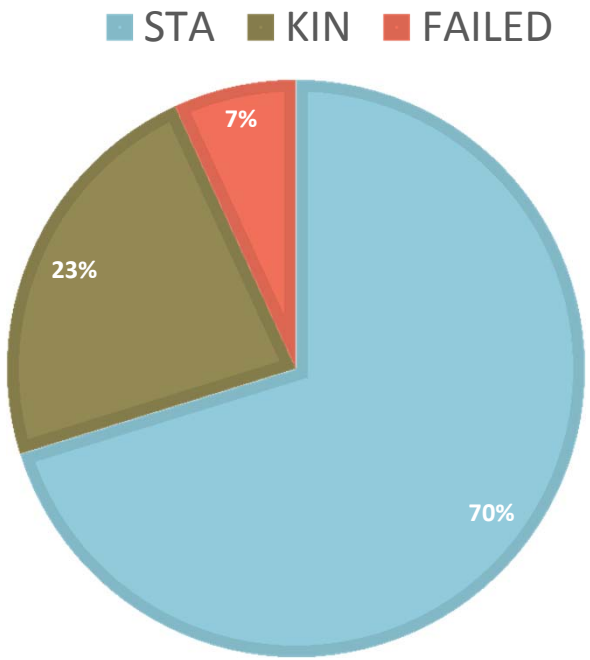


CSRS-PPP – 2018 Software Transition

How did SPARK and GPSPACE results compare?

- Comparison of 16,150 submissions (2018-04-10 to 2018-04-24)

Static	11,439
Kinematic	3494
Failed	1216
Removed	2691
TOTAL	**16,149**



Reasons for failed submissions:

- Pre-processing RINEX QC
  - - e.g. bad format, missing required data
- Post-processing solution QC
  - - e.g. more than 90% of data rejected

CSRS-PPP – Future Plans

- The next major update (SPARK v3) will include Ambiguity Resolution (PPP-AR)
- In conventional PPP, integer phase ambiguities cannot be resolved due to the presence of phase biases
- NRCan is now producing rapid Decoupled Clock Model (DCM) products which support PPP-AR
- Expected benefits include:
  - Higher accuracy for short observation sessions (1-2 hours)
  - Improved longitude estimates for 24-hour static sessions
  - Improved receiver clock and atmospheric delay estimates

CSRS-PPP – Towards Fast Convergence

Satellite orbit and clock corrections

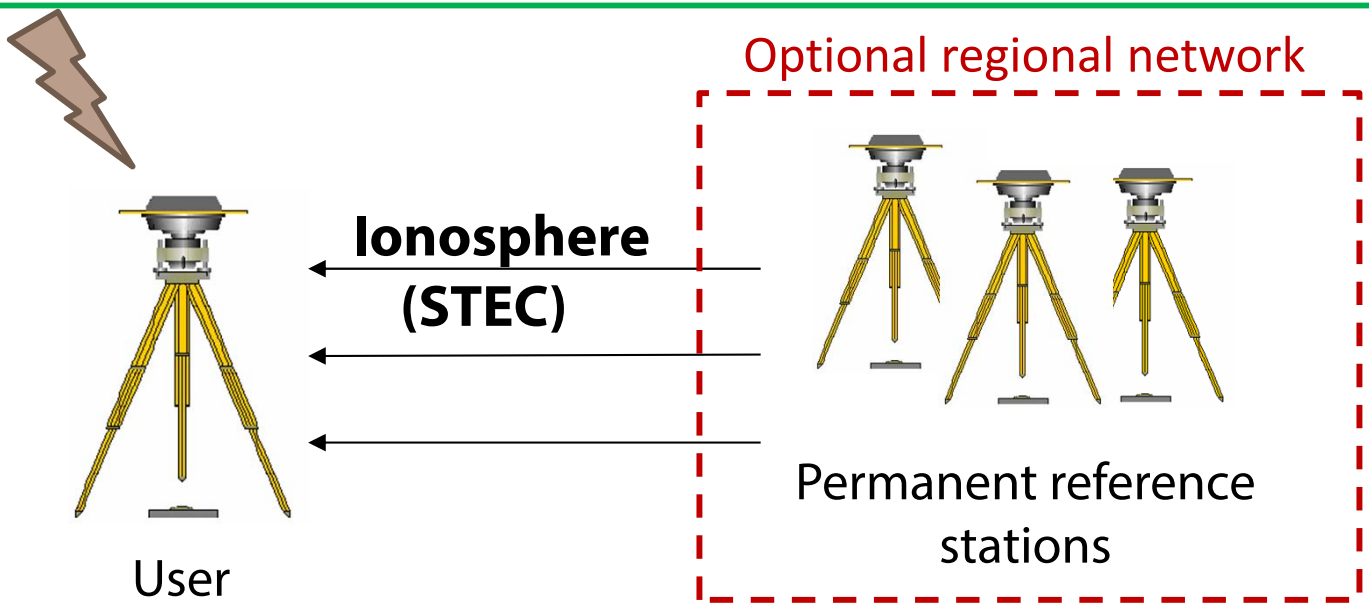
Standard PPP

Next step for CSRS-PPP service

\+

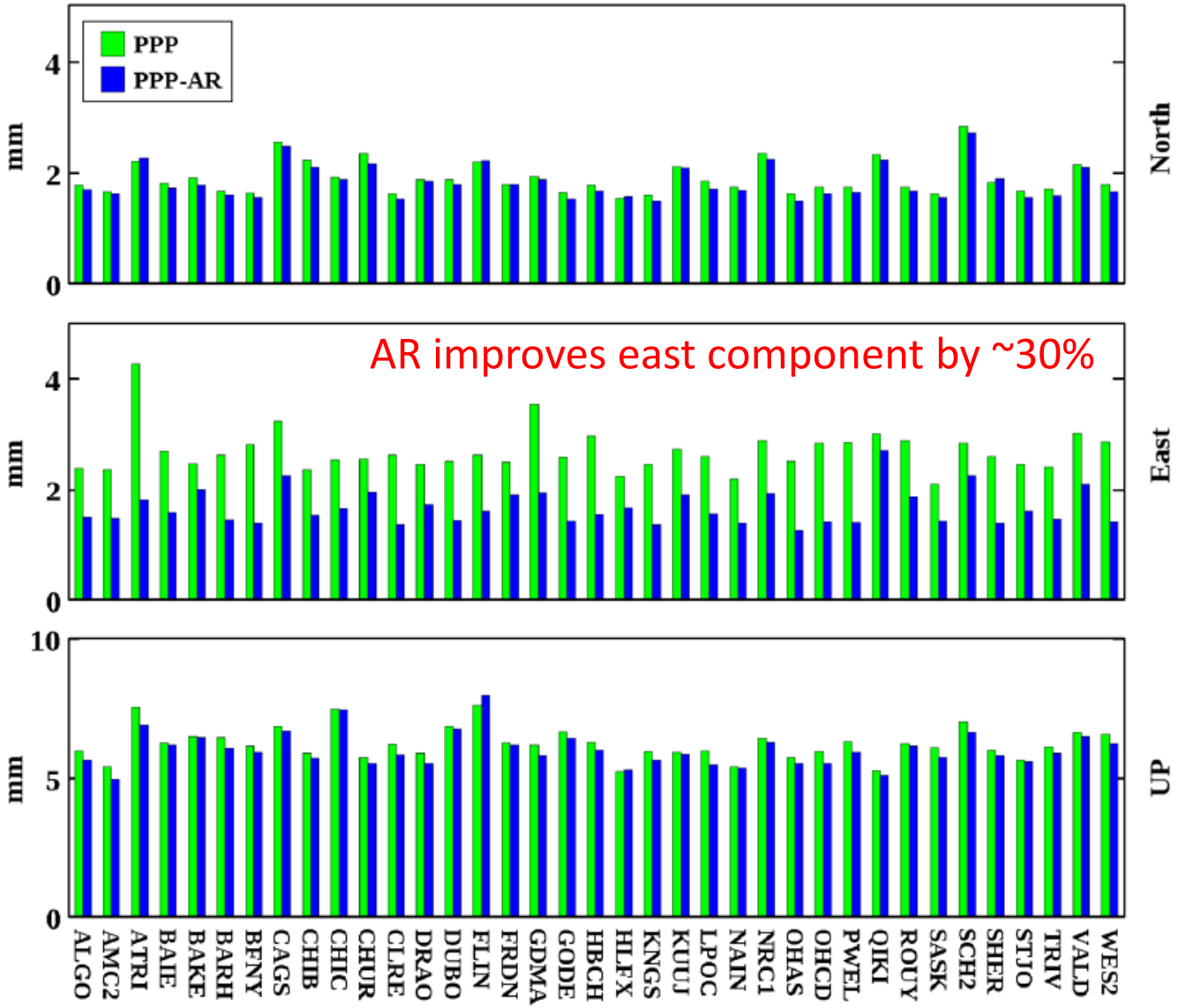
Satellite code and phase biases (Decoupled-Clock Model)

PPP with ambiguity resolution (PPP-AR)



Rapid PPP convergence / Improved single-frequency solutions

PPP-AR Precision (24h Static Solutions)

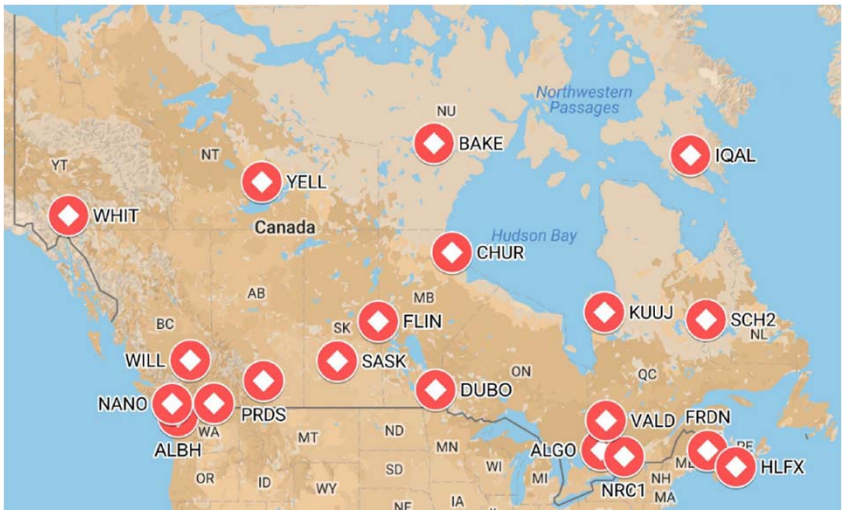


Nearly 40 stations in eastern Canada-US processed over a 10 year period

This plot shows the repeatability of daily positions after removing linear and seasonal trends.

CSRS-PPP v3 Accuracy Analysis

Data set: 20 stations, 1 day/week for 52 weeks (2018)

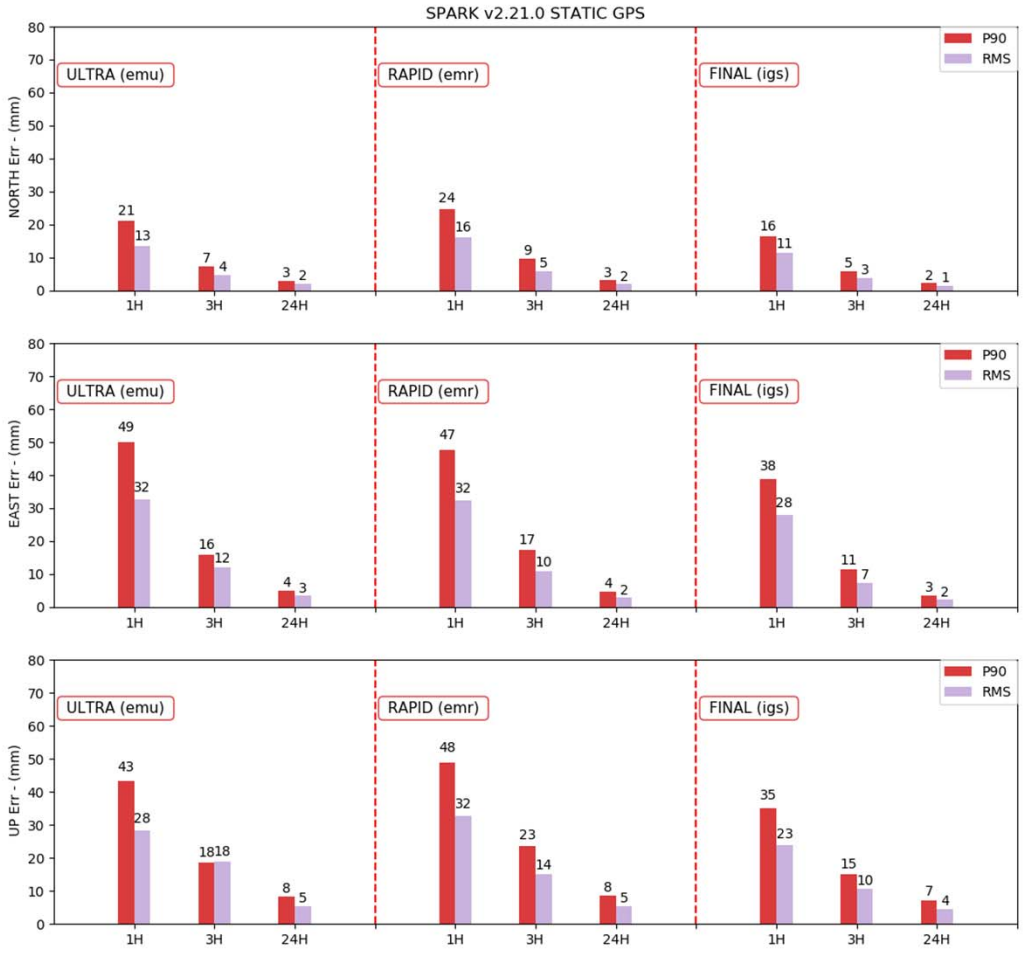


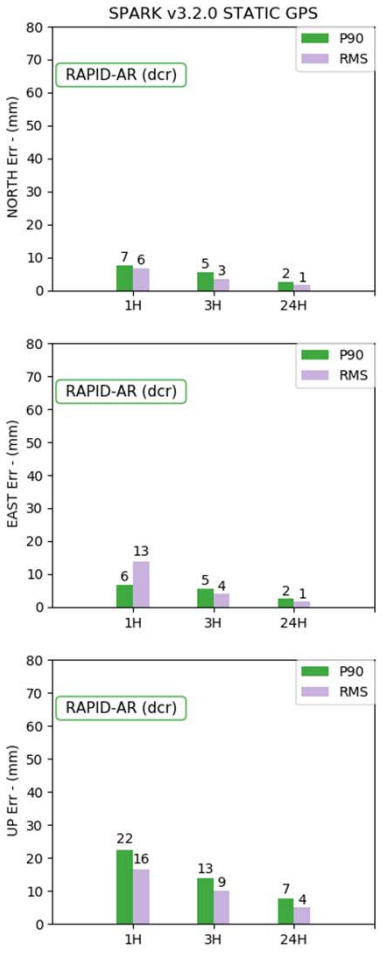
PPP-Processing:

- 1013 RINEX files
- 1h, 3h, and 24h observation sessions from each file
- Mode: Static & Kinematic
- Systems: GPS-only & GPS + GLONASS
- SPARK versions: v2.21.0 & v3.2.0

CSRS-PPP v3 Accuracy Analysis

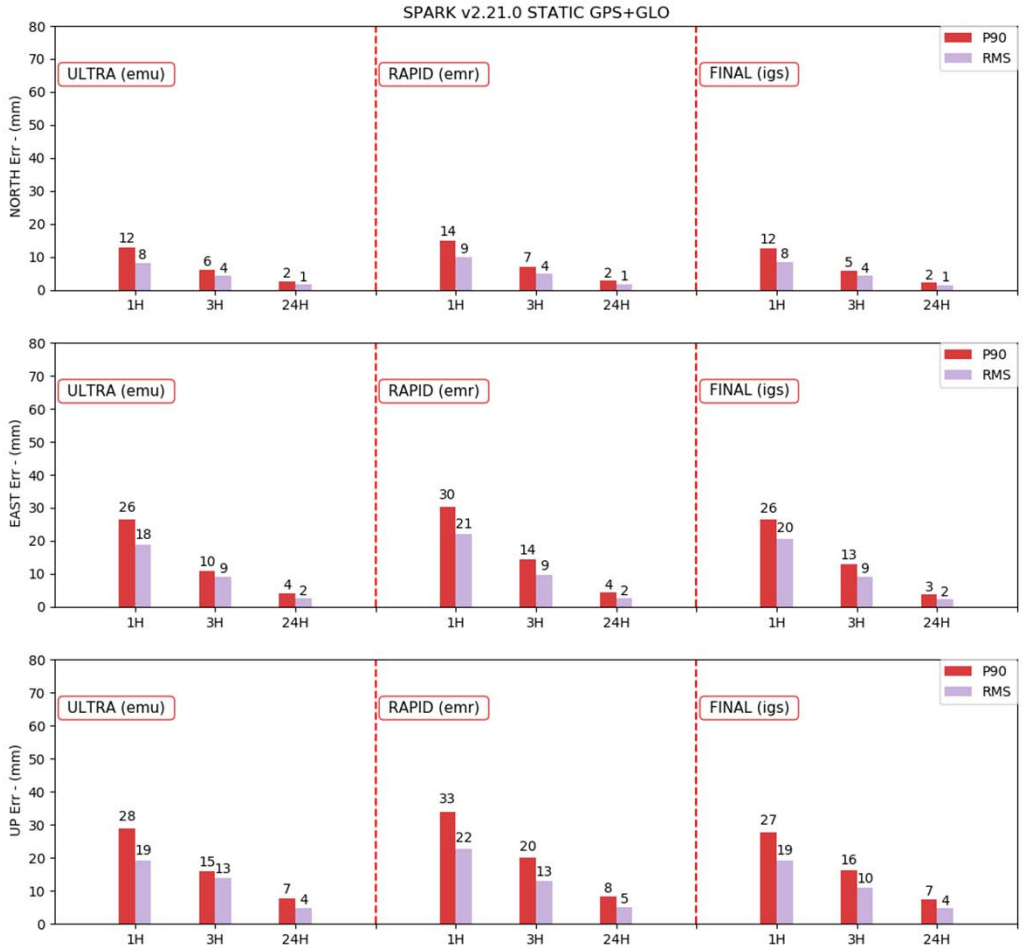
STATIC - GPS

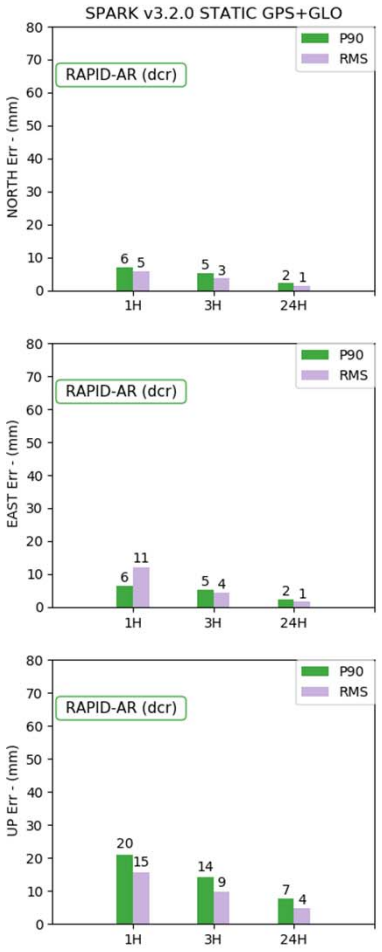




CSRS-PPP v3 Accuracy Analysis

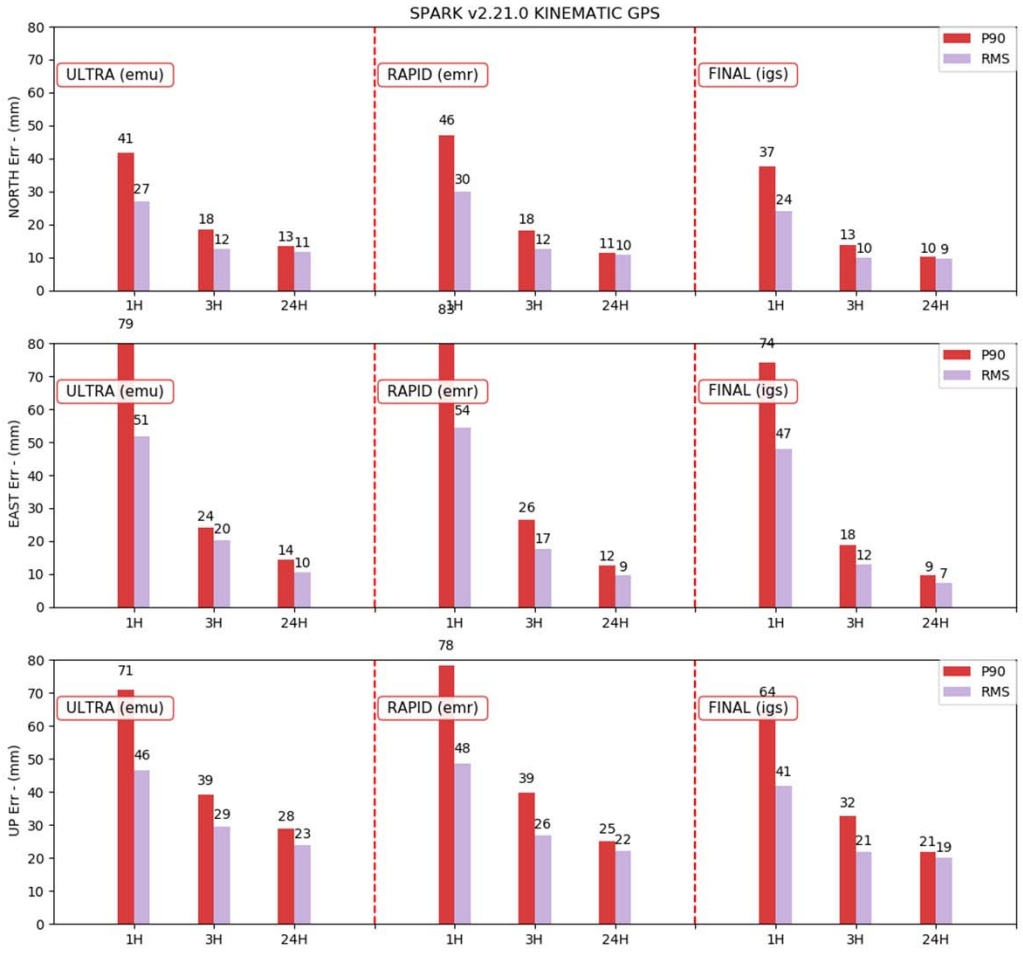
STATIC – GPS+GLONASS

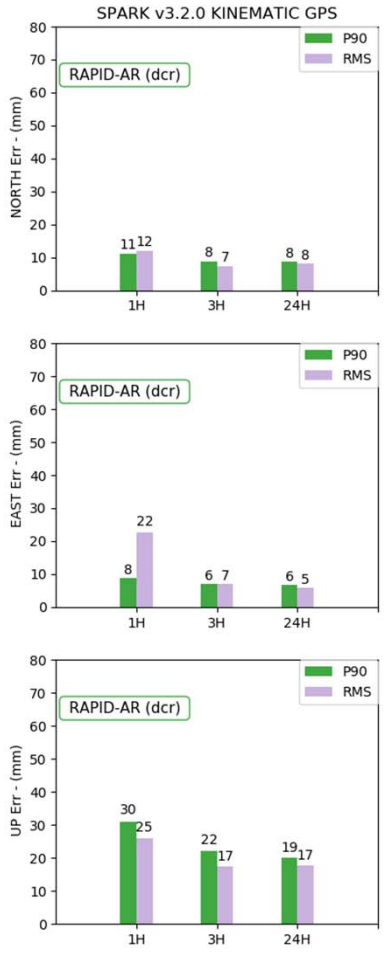




CSRS-PPP v3 Accuracy Analysis

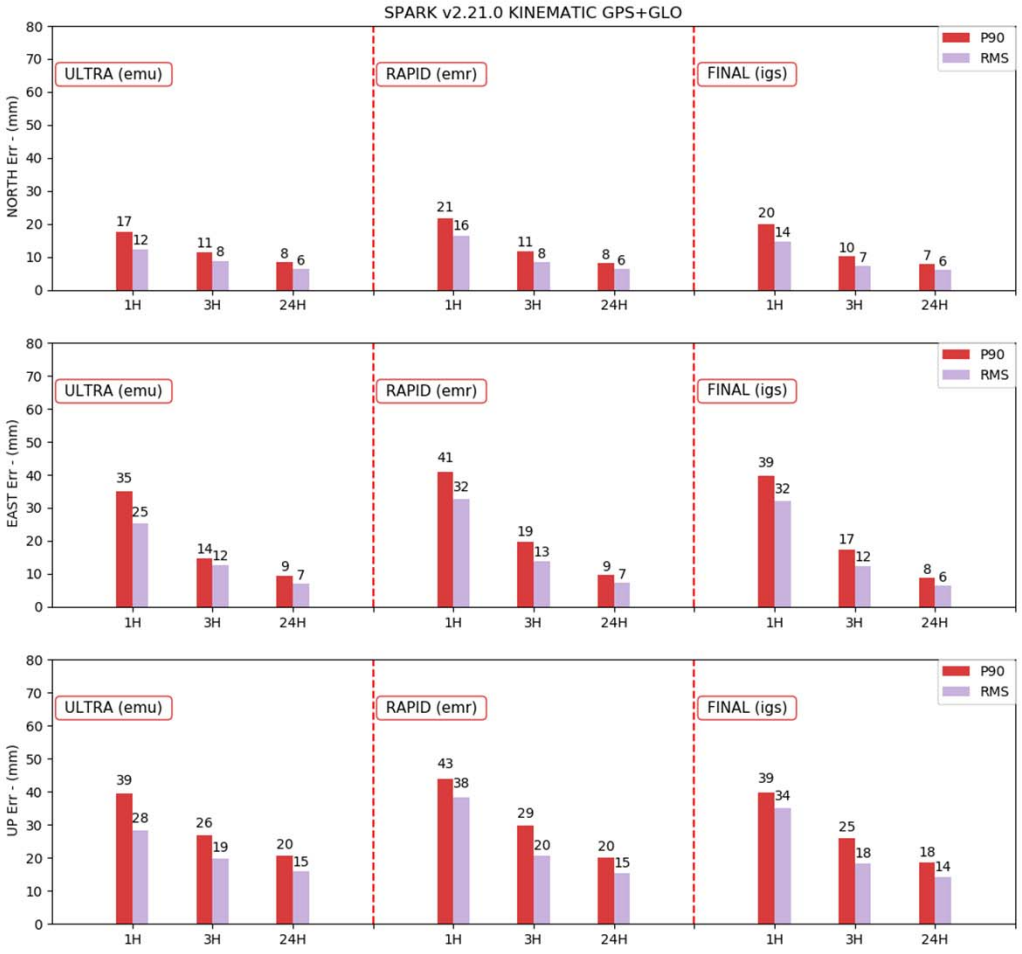
KINEMATIC - GPS

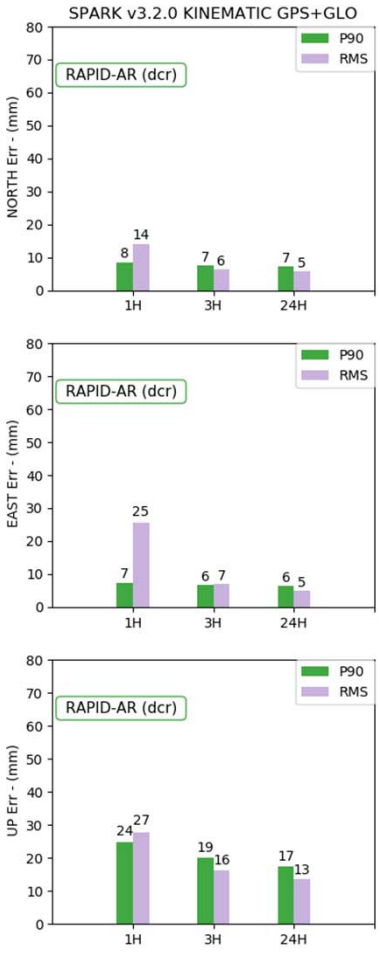




CSRS-PPP v3 Accuracy Analysis

KINEMATIC – GPS+GLONASS



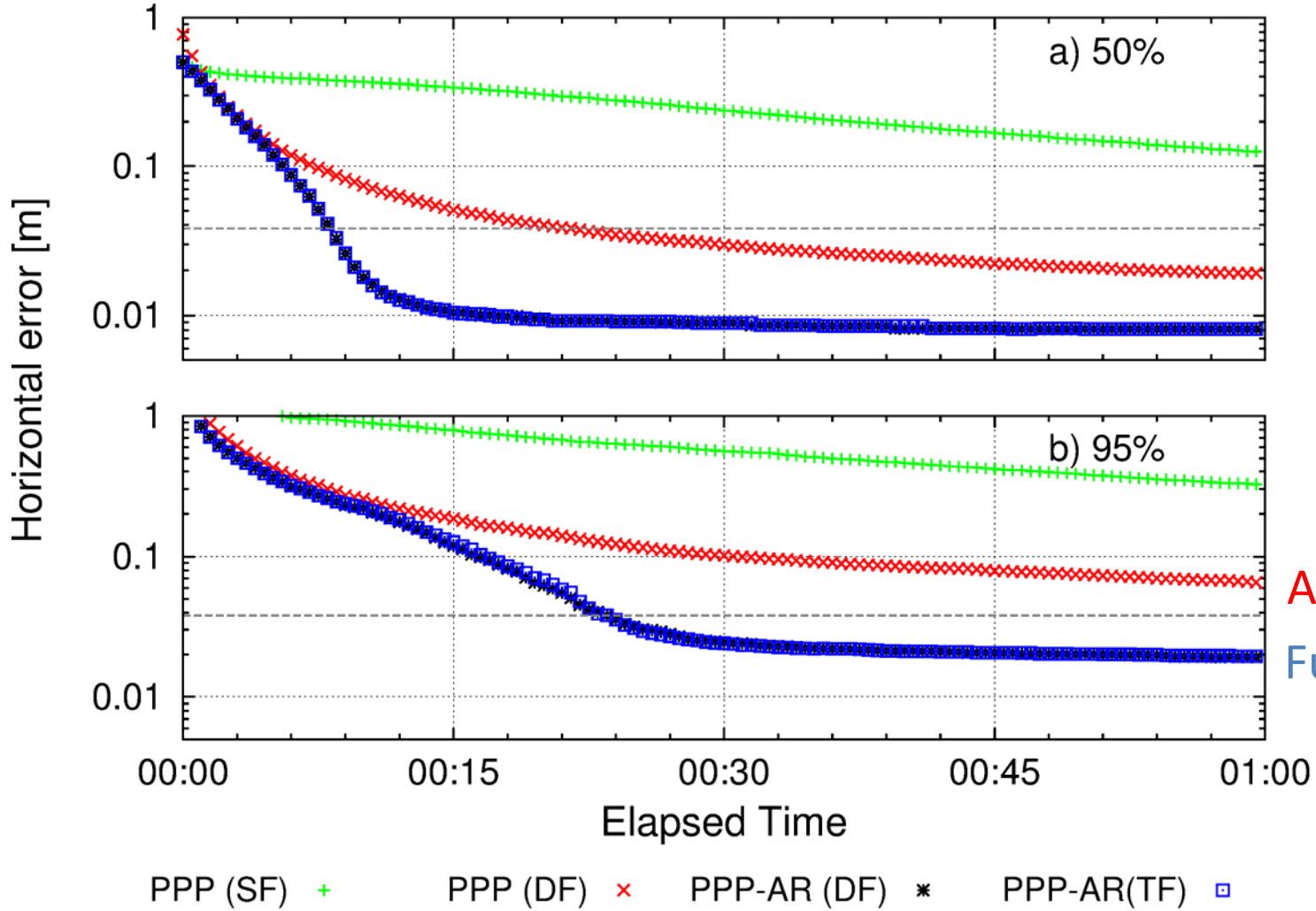


PPP-AR Convergence Analysis

- 7 days of data: August 14-20, 2016
- ~40 globally-distributed stations using 30-sec data divided in hourly sessions
- 4 solutions analyzed:

Solutions	Frequencies	Systems	Ambiguity Resolution	STEC Constraints
PPP (SF)	L1	GPS + GLONASS	No	GIM
PPP (DF)	L1 / L2	GPS + GLONASS	No	No
PPP-AR (DF)	L1 / L2	GPS + GLONASS	GPS	GIM
PPP-AR (TF)	L1 / L2 / L5 (GPS)	GPS + GLONASS	GPS	GIM

PPP-AR Convergence Results



Actual service

Future service

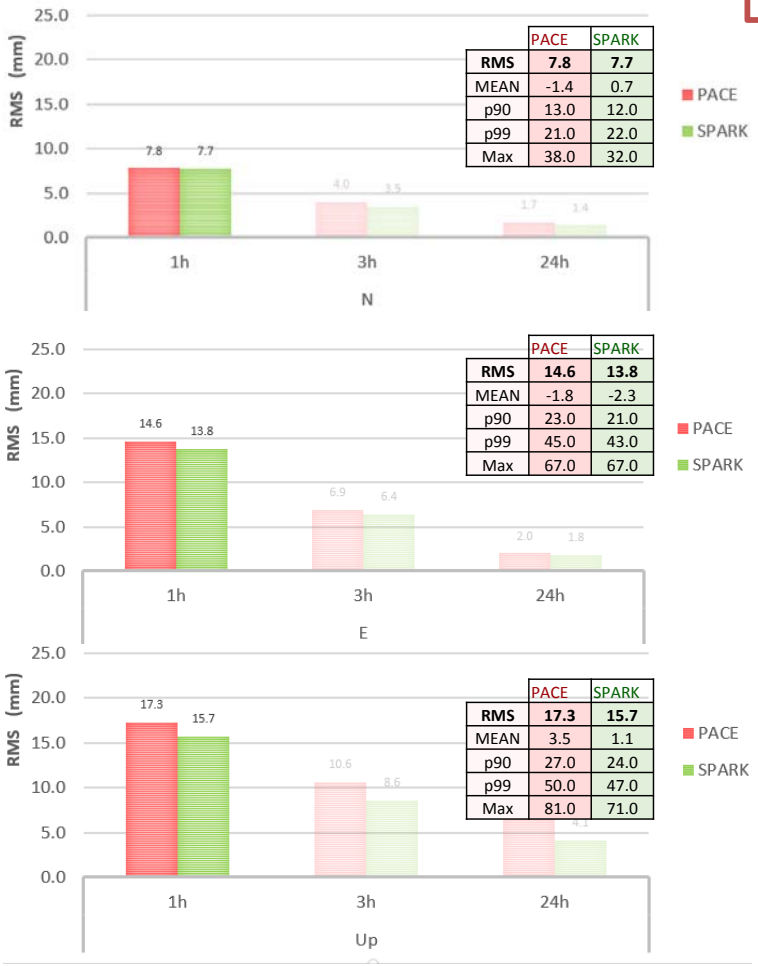
* May allow for shorter on-site occupation times

CSRS-PPP – SPARK Accuracy Analysis

Results

Static - GPS + GLONASS

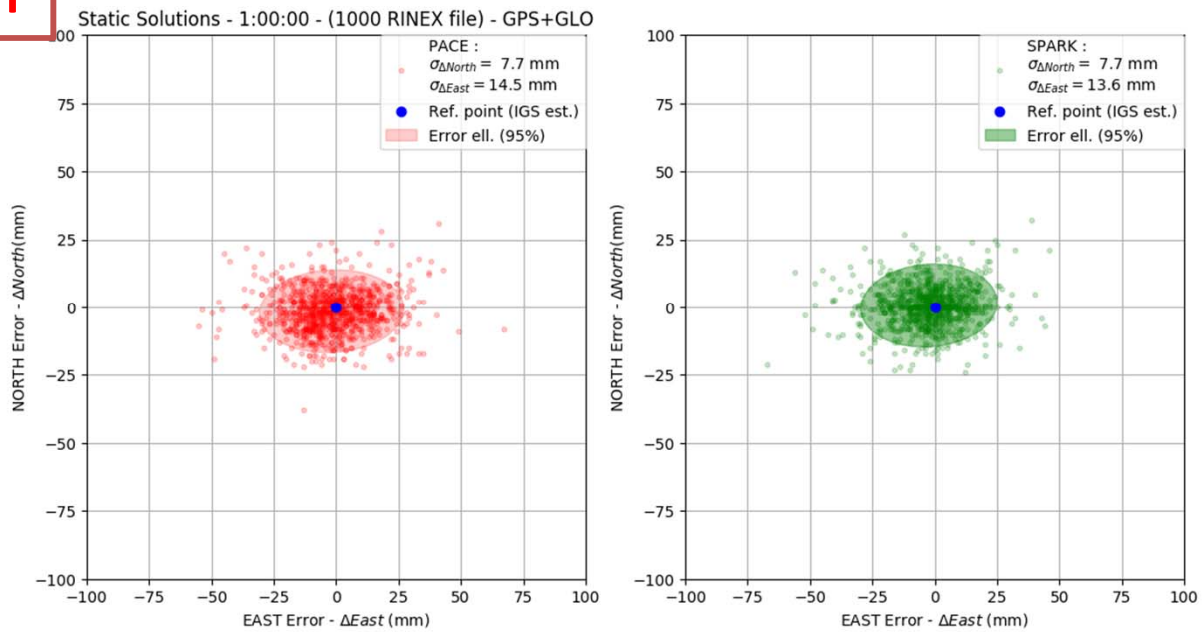
1H

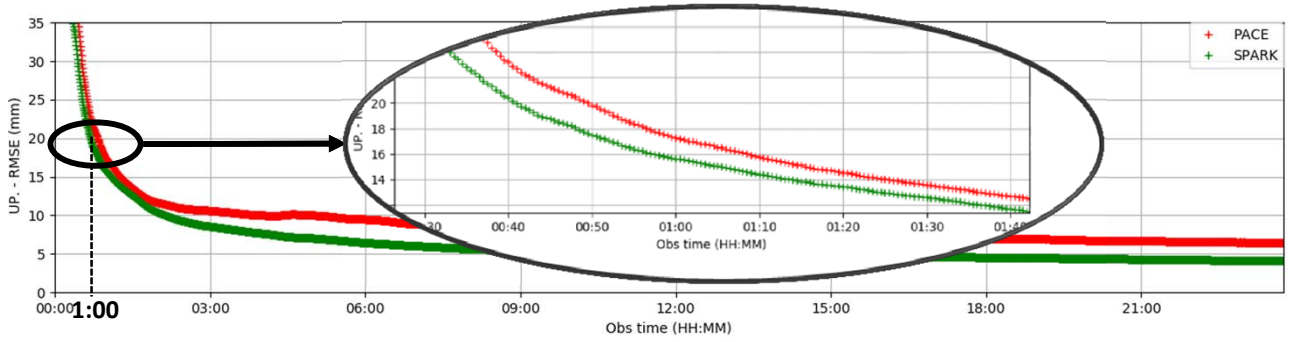


	PACE	SPARK
RMS	**7.8**	**7.7**
MEAN	-1.4	0.7
p90	13.0	12.0
p99	21.0	22.0
Max	38.0	32.0

	PACE	SPARK
RMS	**14.6**	**13.8**
MEAN	-1.8	-2.3
p90	23.0	21.0
p99	45.0	43.0
Max	67.0	67.0

	PACE	SPARK
RMS	**17.3**	**15.7**
MEAN	3.5	1.1
p90	27.0	24.0
p99	50.0	47.0
Max	81.0	71.0



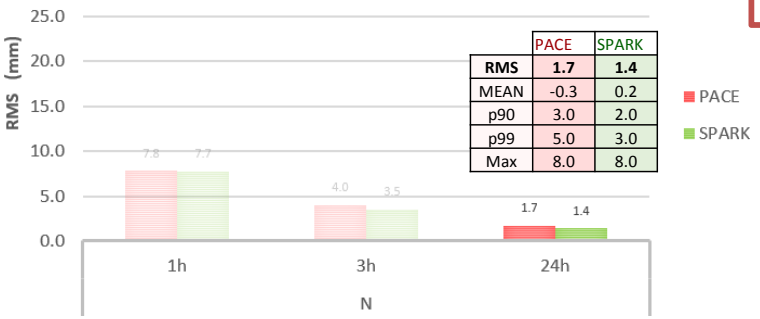


CSRS-PPP – SPARK Accuracy Analysis

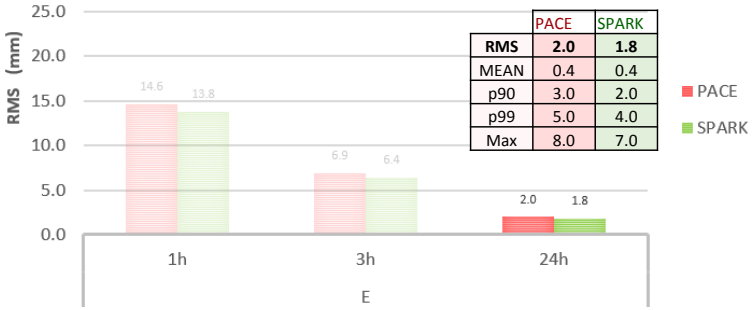
Results

Static - GPS + GLONASS

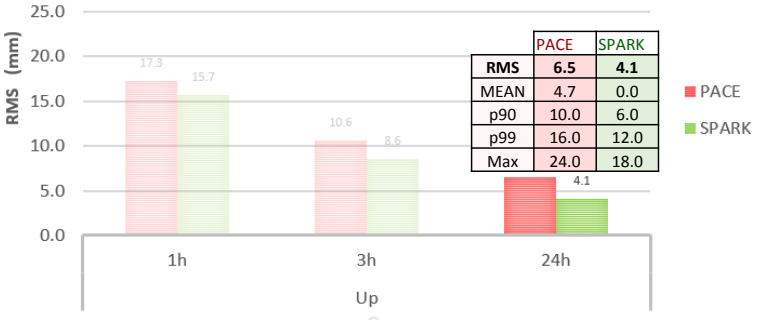
24H



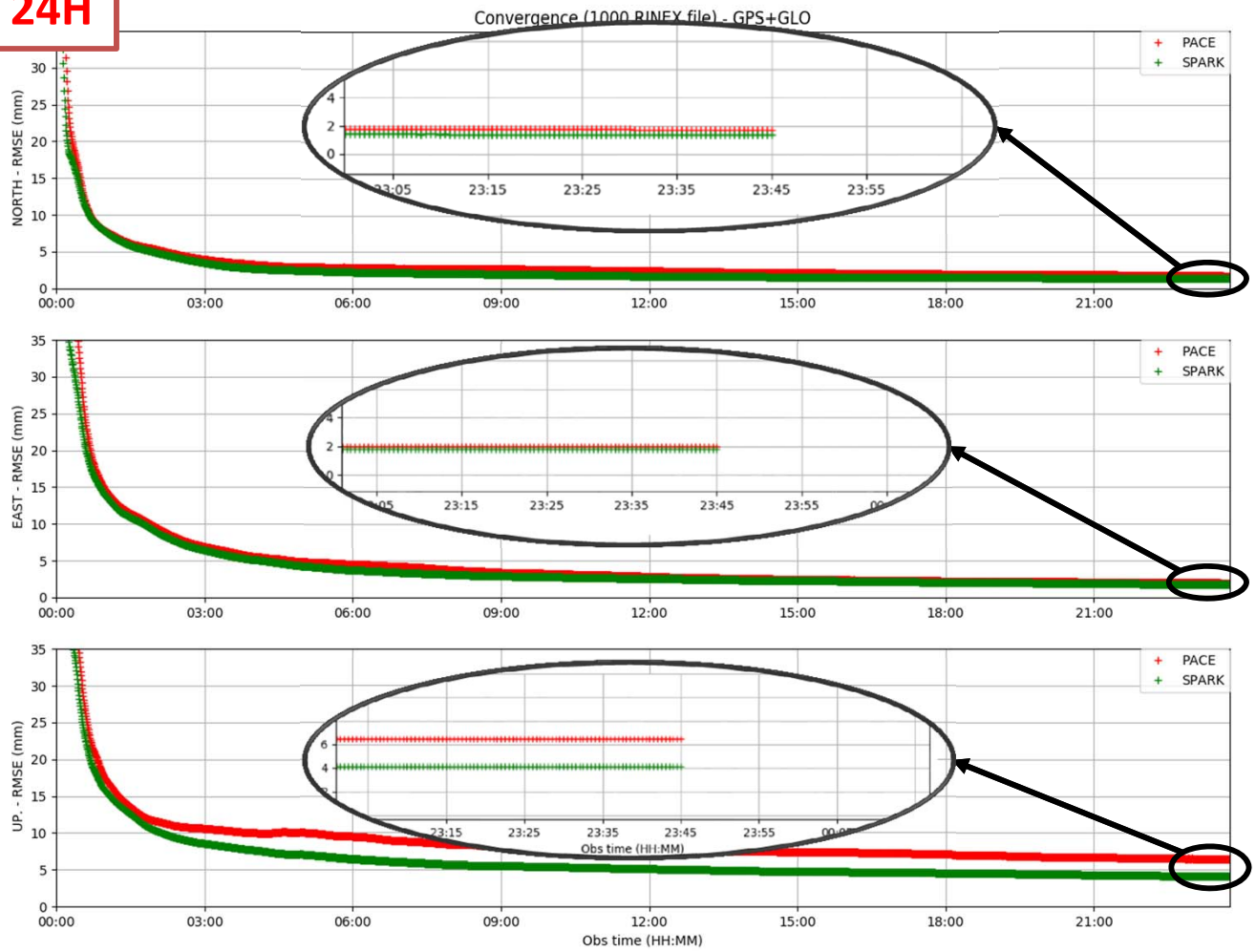
	PACE	SPARK
RMS	**1.7**	**1.4**
MEAN	-0.3	0.2
p90	3.0	2.0
p99	5.0	3.0
Max	8.0	8.0



	PACE	SPARK
RMS	**2.0**	**1.8**
MEAN	0.4	0.4
p90	3.0	2.0
p99	5.0	4.0
Max	8.0	7.0



	PACE	SPARK
RMS	**6.5**	**4.1**
MEAN	4.7	0.0
p90	10.0	6.0
p99	16.0	12.0
Max	24.0	18.0

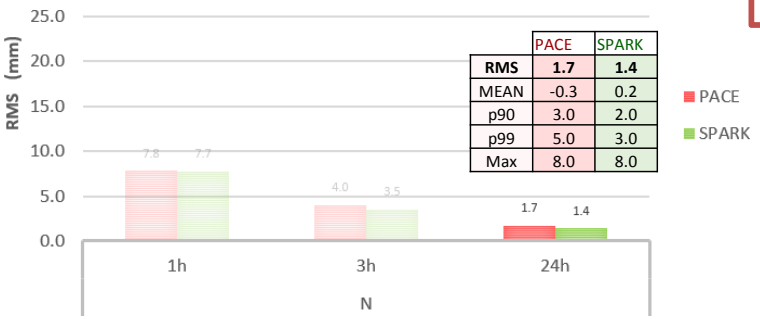


CSRS-PPP – SPARK Accuracy Analysis

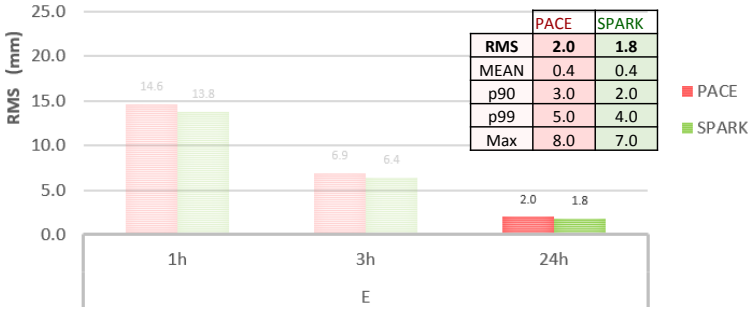
Results

Static - GPS + GLONASS

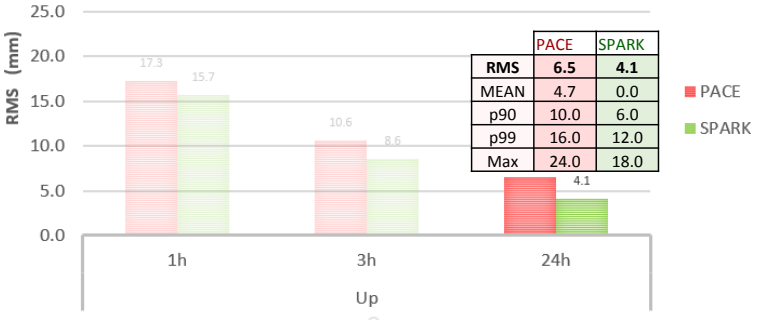
24H



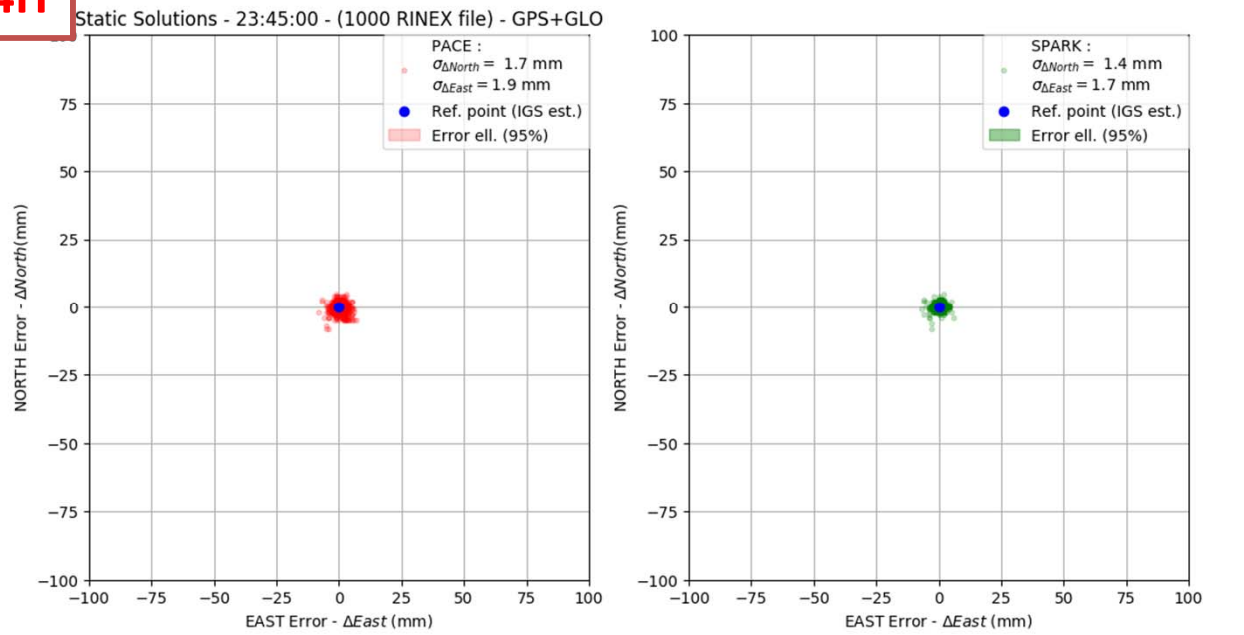
	PACE	SPARK
RMS	**1.7**	**1.4**
MEAN	-0.3	0.2
p90	3.0	2.0
p99	5.0	3.0
Max	8.0	8.0

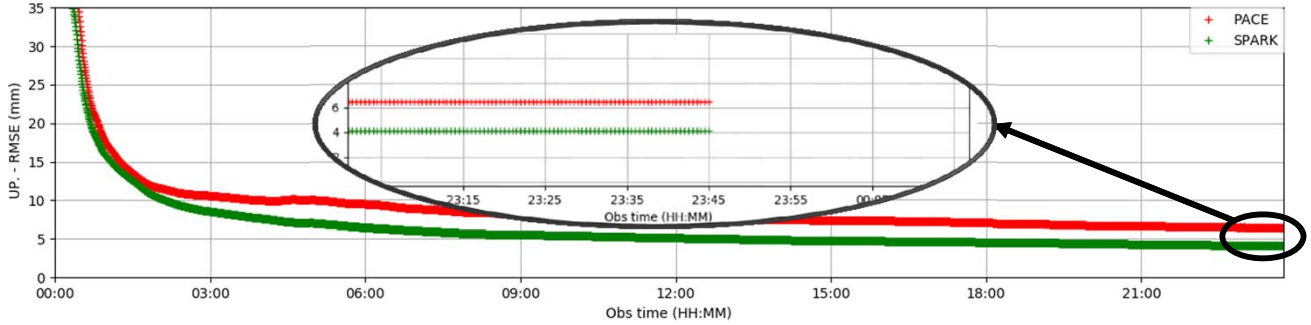


	PACE	SPARK
RMS	**2.0**	**1.8**
MEAN	0.4	0.4
p90	3.0	2.0
p99	5.0	4.0
Max	8.0	7.0



	PACE	SPARK
RMS	**6.5**	**4.1**
MEAN	4.7	0.0
p90	10.0	6.0
p99	16.0	12.0
Max	24.0	18.0



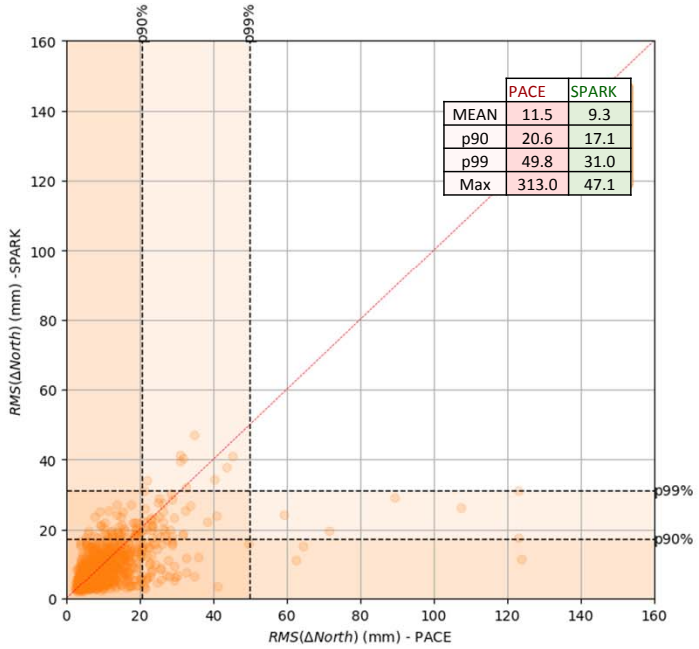


CSRS-PPP – SPARK Accuracy Analysis

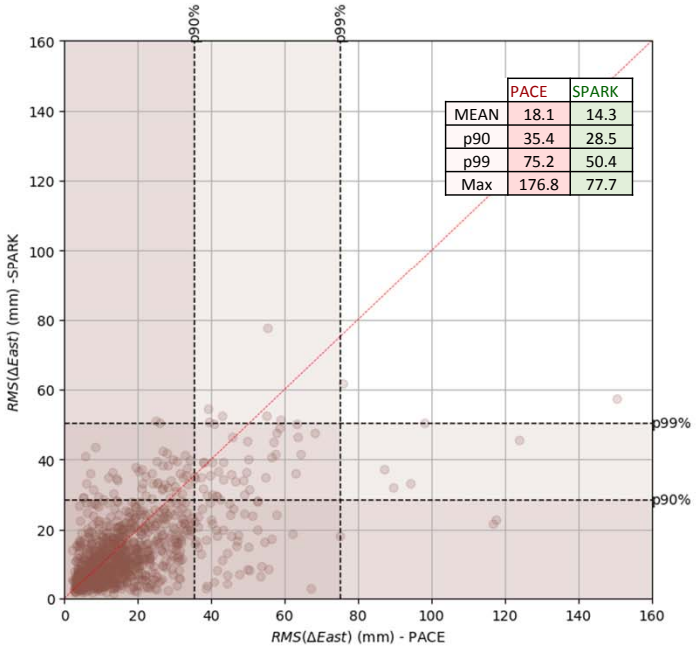
Results

Kinematic – GPS + GLONASS – Obs. time: 1h

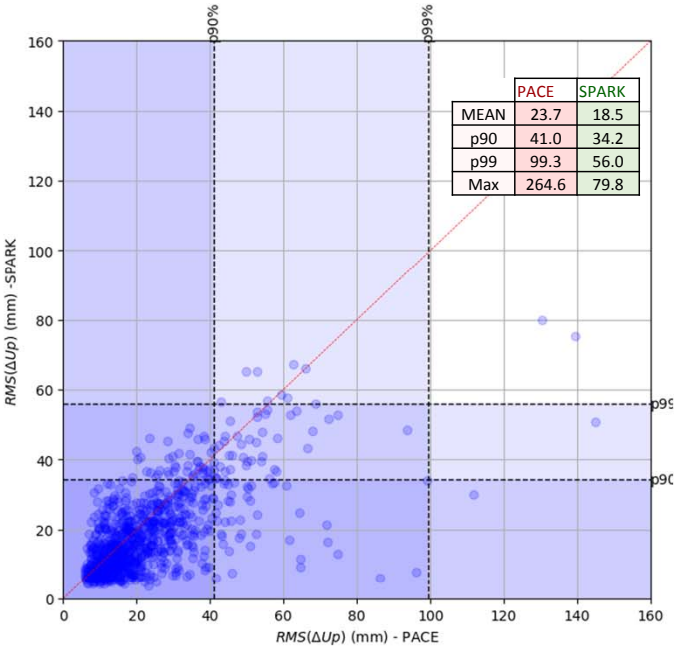
RMS of estimated positions over all epochs



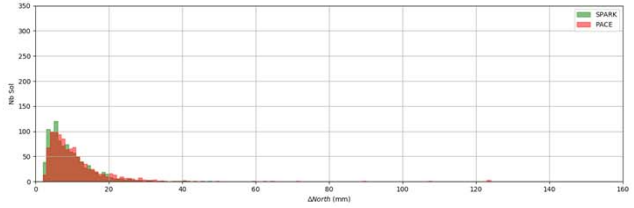
	PACE	SPARK
MEAN	11.5	9.3
p90	20.6	17.1
p99	49.8	31.0
Max	313.0	47.1

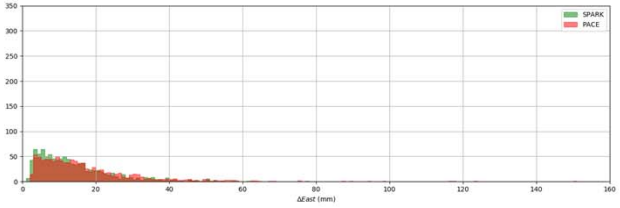


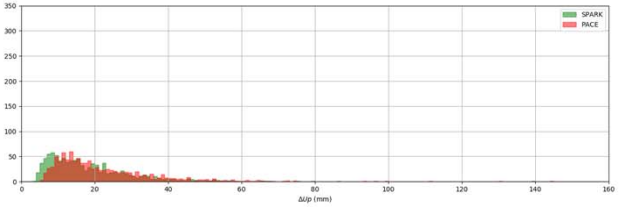
	PACE	SPARK
MEAN	18.1	14.3
p90	35.4	28.5
p99	75.2	50.4
Max	176.8	77.7



	PACE	SPARK
MEAN	23.7	18.5
p90	41.0	34.2
p99	99.3	56.0
Max	264.6	79.8





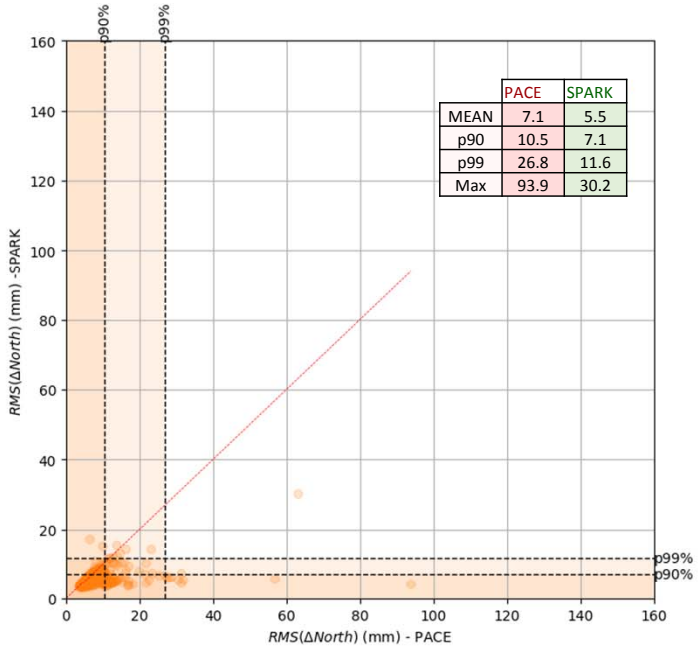


CSRS-PPP – SPARK Accuracy Analysis

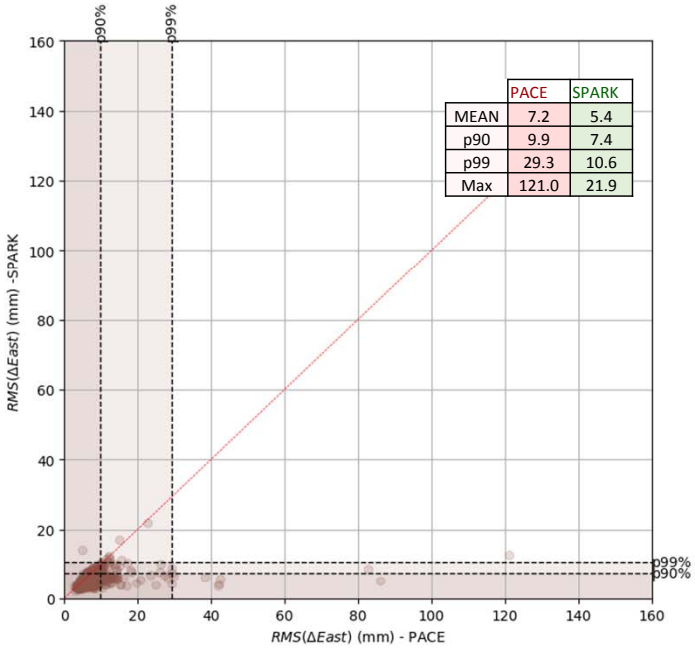
Results

Kinematic – GPS + GLONASS – Obs. time: 23h 45min

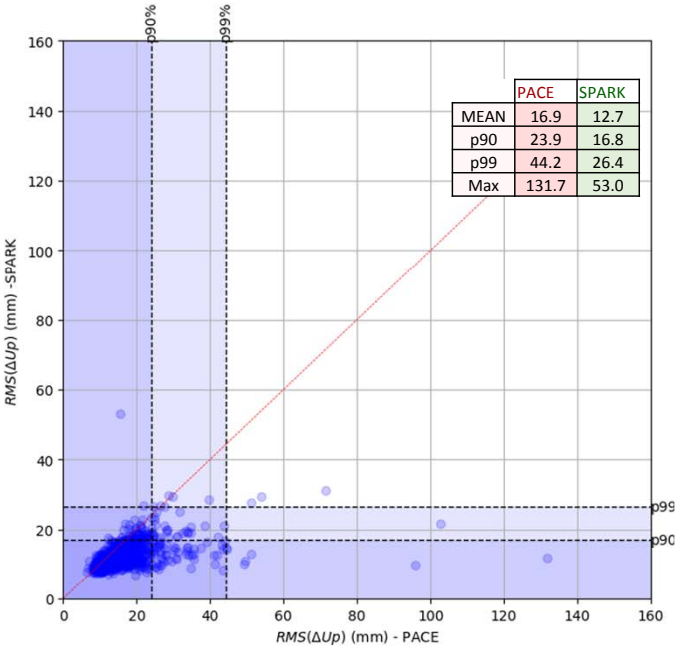
RMS of estimated positions over all epochs



	PACE	SPARK
MEAN	7.1	5.5
p90	10.5	7.1
p99	26.8	11.6
Max	93.9	30.2



	PACE	SPARK
MEAN	7.2	5.4
p90	9.9	7.4
p99	29.3	10.6
Max	121.0	21.9



	PACE	SPARK
MEAN	16.9	12.7
p90	23.9	16.8
p99	44.2	26.4
Max	131.7	53.0