

From IGS Products to User Solutions: Canada's CSRS-PPP Service

Authors: E. HASSEN, S. BANVILLE, B. DONAHUE, J. FARINACCIO, A. FARINEAU and M. WALKER
Canadian Geodetic Survey, Natural Resources Canada



INTRODUCTION

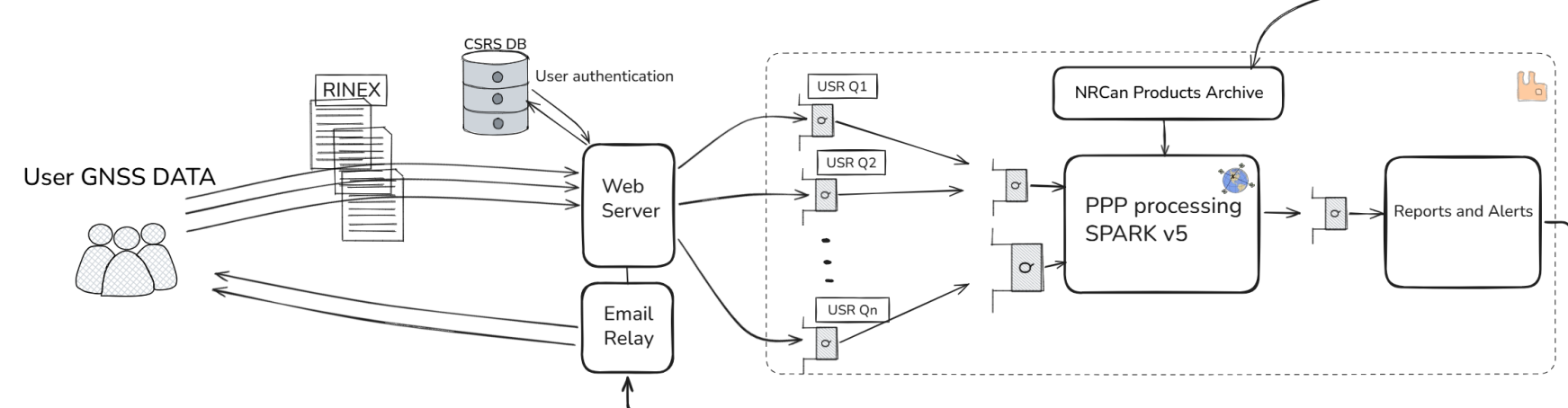
Natural Resources Canada's (NRCan) Canadian Geodetic Survey (CGS) maintains the Canadian Spatial Reference System (CSRS), the national framework that enables accurate and consistent positioning across Canada. A key component is CSRS-PPP, a free online post-processed GNSS positioning service powered by precise products from the International GNSS Service (IGS) and the Canadian Geodetic Survey. In operation since 2003, CSRS-PPP provides high-precision access to both the IGS realization of the International Terrestrial Reference Frame (ITRF) and Canada's national standard: NAD83(CRSR). The service features a multi-GNSS PPP-AR engine and a scalable architecture capable of processing tens of thousands of GNSS files daily.

This poster outlines the system's architecture, processing strategy, and the roles of IGS and internal products. It also highlights major milestones of the service and recent updates—such as support for Galileo and the integration of IGS Repro3—and evaluates their effects on precision, accuracy, and convergence. It also shows an evaluation of the recent IGS combined demonstration (DEM) multi-GNSS (GPS, Galileo, GLONASS) Final products and demonstrates the benefits that these products can bring to the CSRS-PPP service.

SERVICE ARCHITECTURE

CSRS-PPP is a fully automated end-to-end service which post-processes user submitted RINEX files using the most precise products available. Processing relies on one of three product streams — Final, Rapid, or Ultra-rapid — depending on product availability. Multi-GNSS Final and Rapid products are generated from combinations of products from multiple IGS Analysis Centers (ACs), while NRCan produces its own GPS and GLONASS Ultra-rapid (hourly) products.

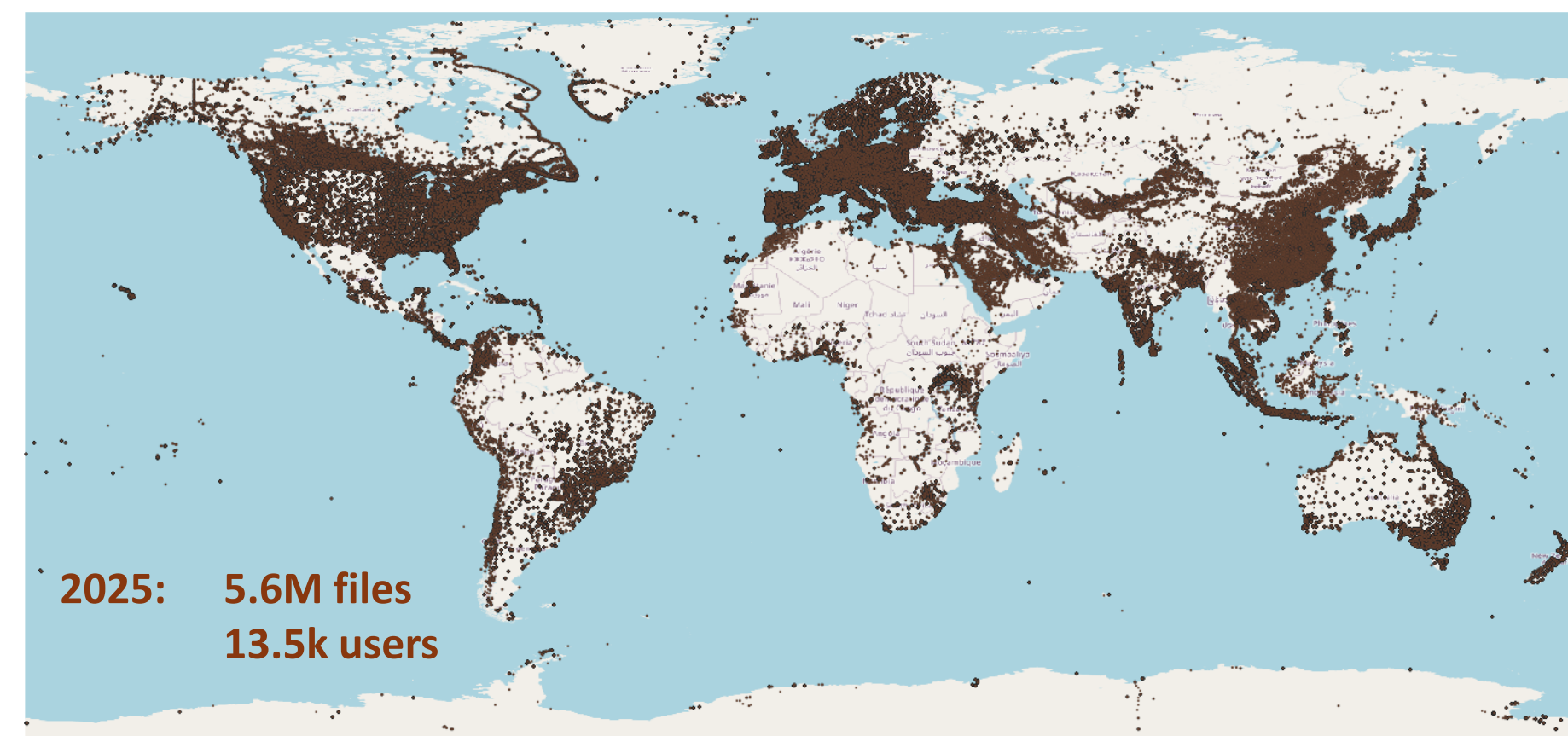
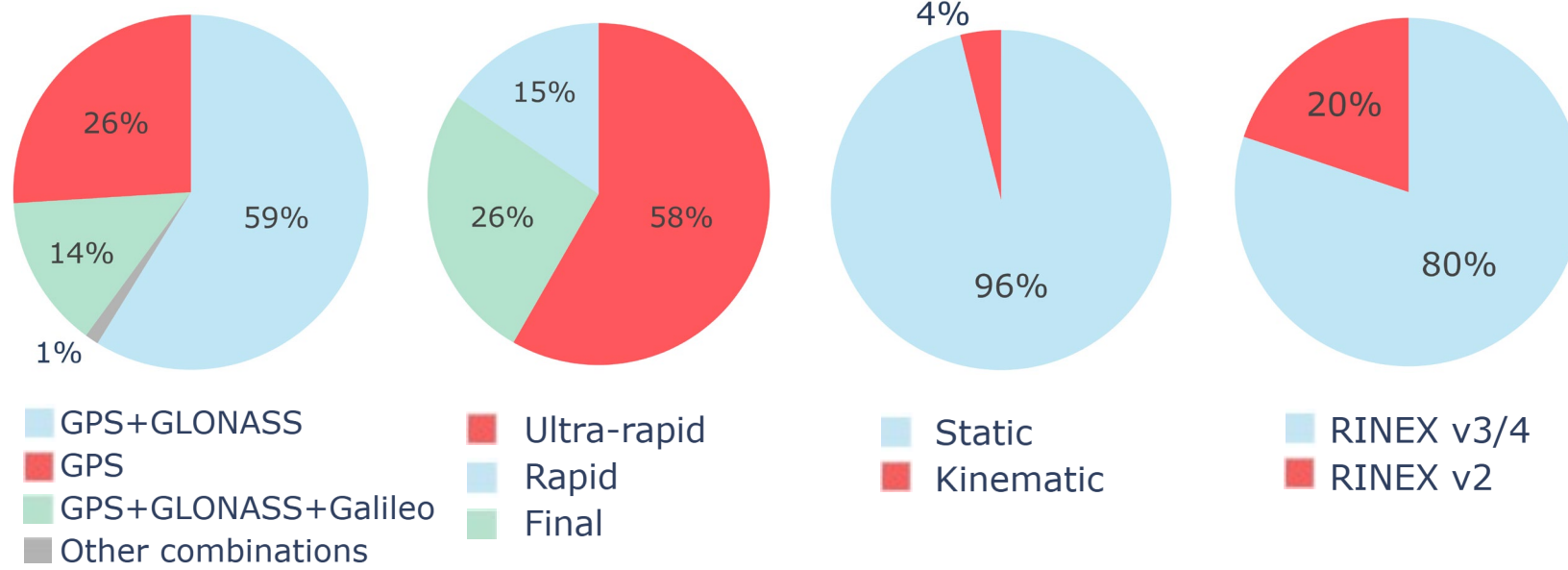
The following diagram provides a simplified overview of the CSRS-PPP online service and highlights the sources of the products used during processing.



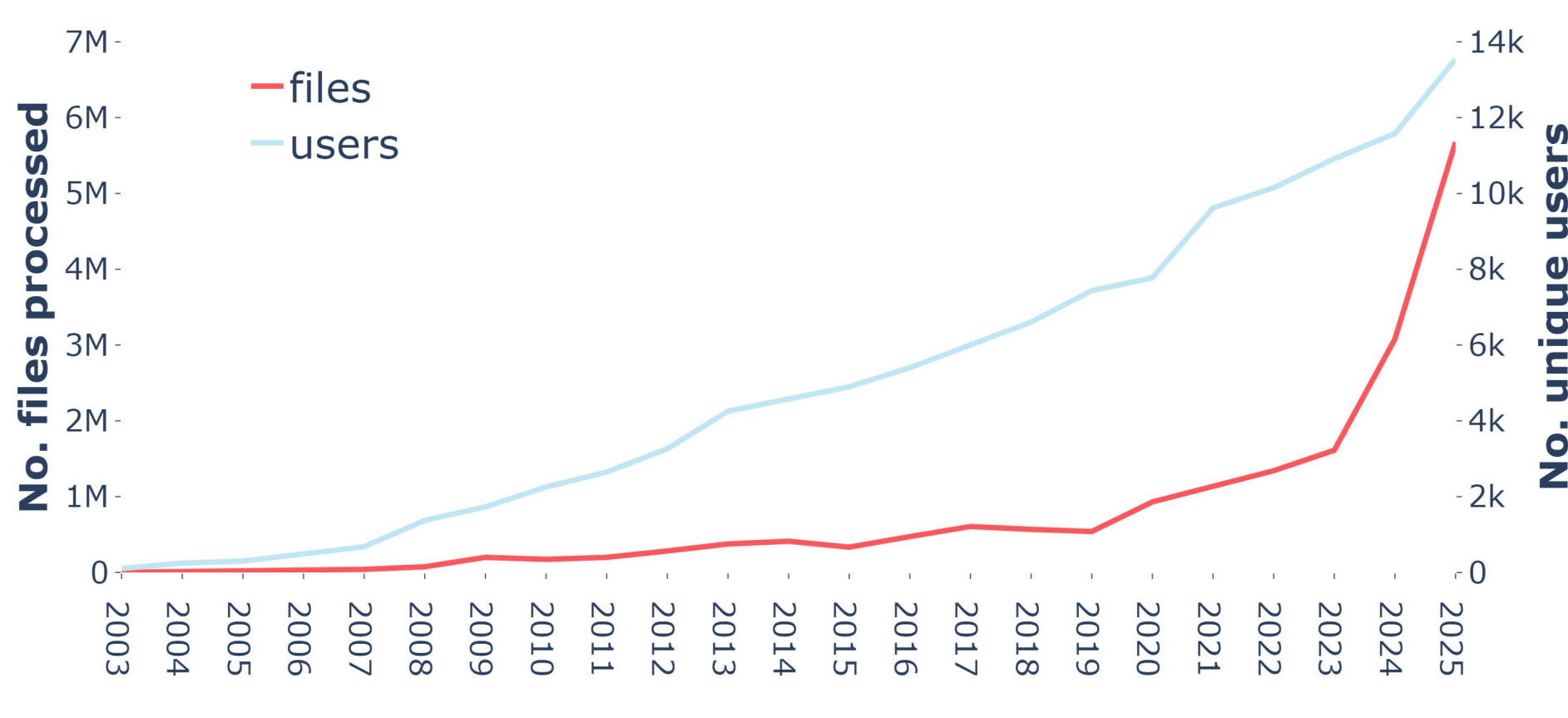
	Product line	Final			Rapid			Ultra		
		G	E		G	E		G	E	
IGS	Precise Orbits	✓	✓		✓	✓		✓	✓	
Operational products	Clock products	✓	✓		✓	✓		✓	✓	
	Earth Rotation Parameters	✓	✓		✓	✓		✓	✓	
	Satellite attitude products	✓	✓		✓	✓		✓	✓	
	OSR Biases	✓	✓		✓	✓		✓	✓	
Center for Orbit Determination in Europe (CODE)	Precise Orbits	✓	✓		✓	✓		✓	✓	
	Clock products	✓	✓		✓	✓		✓	✓	
	Earth Rotation Parameters	✓	✓		✓	✓		✓	✓	
	Satellite attitude products	✓	✓		✓	✓		✓	✓	
	OSR Biases	✓	✓		✓	✓		✓	✓	
NRCan analysis center (SPK)	Precise Orbits	✓	✓		✓	✓		✓	✓	
	Clock products	✓	✓		✓	✓		✓	✓	
	Earth Rotation Parameters	✓	✓		✓	✓		✓	✓	
	Satellite attitude products	✓	✓		✓	✓		✓	✓	
	OSR Biases	✓	✓		✓	✓		✓	✓	
	Day boundary discontinuities	✓	✓		✓	✓		✓	✓	
	Ionosphere Maps (GIM)	✓	✓		✓	✓		✓	✓	
	OSR Biases	✓	✓		✓	✓		✓	✓	
IGSAC	IGS satellite metadata	✓	✓		✓	✓		✓	✓	
	Antenna Calibrations	✓	✓		✓	✓		✓	✓	
TU Wien	Tropospheric products	✓	✓		✓	✓		✓	✓	
NRCan using GIM	GIM displacement	✓	✓		✓	✓		✓	✓	

*Satellite clock and bias combination using products enabling PPP-AR provided by various IGS analysis centers.

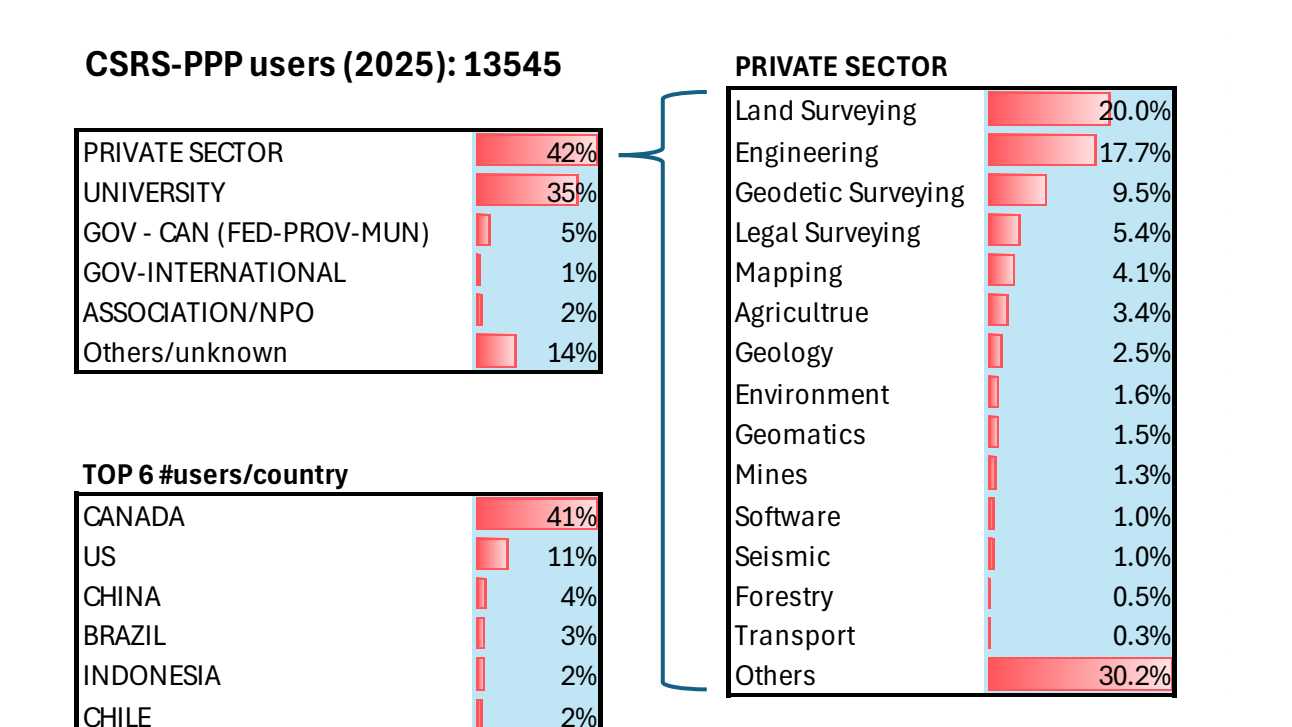
NUMBER AND TYPES OF FILES PROCESSED IN 2025 BY CSRS-PPP



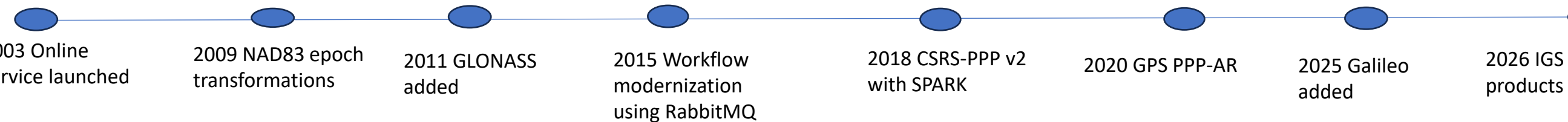
CSRS-PPP USAGE



WHO ARE THE USERS OF CSRS-PPP?



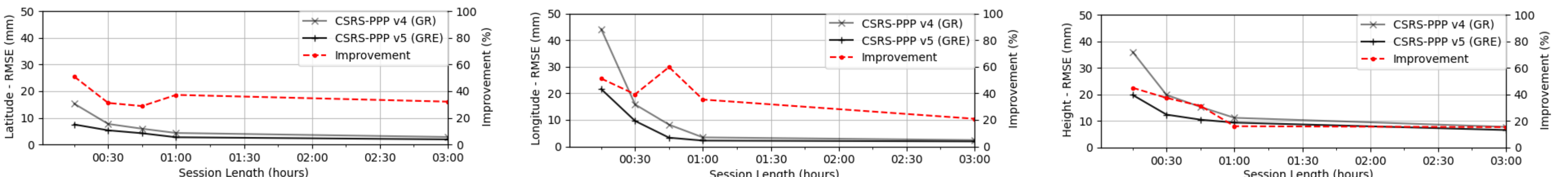
MAJOR MILESTONES



RECENT UPDATES

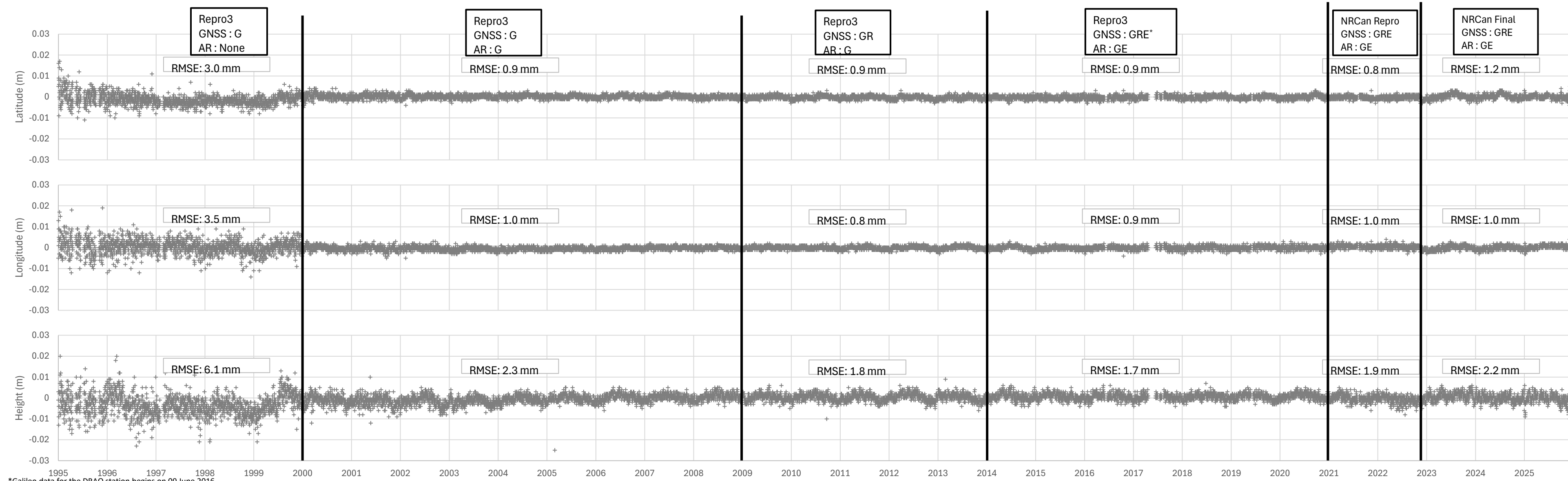
Galileo integration

In May 2025, NRCan modernized the CSRS-PPP service from **version 4 to version 5** to support Galileo PPP with ambiguity resolution (Galileo PPP-AR) for E1/E5a observations when processed with either Rapid or Final products. This enhancement combines operational IGS Final and Rapid GPS orbit products with NRCan in-house combined GPS clocks and phase biases, together with CODE Final and Rapid GLONASS and Galileo products. The following figures illustrate the improvements brought by version 5 to the convergence of PPP solutions for sessions of less than 3 hours:



IGS Repro3 Products

In January 2026, CSRS-PPP was updated to use IGS Repro3 products for observations collected before 27 November 2022. This update enables support for GPS observations beginning on 1 January 1995, GLONASS observations beginning on 2 January 2009, and Galileo observations beginning on 1 January 2014. The following figure shows the difference between CSRS-PPP and IGS daily combined solutions for the station DRAO (Canada) from 1 January 1995 to 31 December 2025. Overall, the Repro3 products demonstrate good agreement with the reference solutions and appear to slightly outperform the current Final products. However, an annual signal is evident in the DRAO time series. This signal is not consistently observed across all processed stations and therefore warrants further investigation.



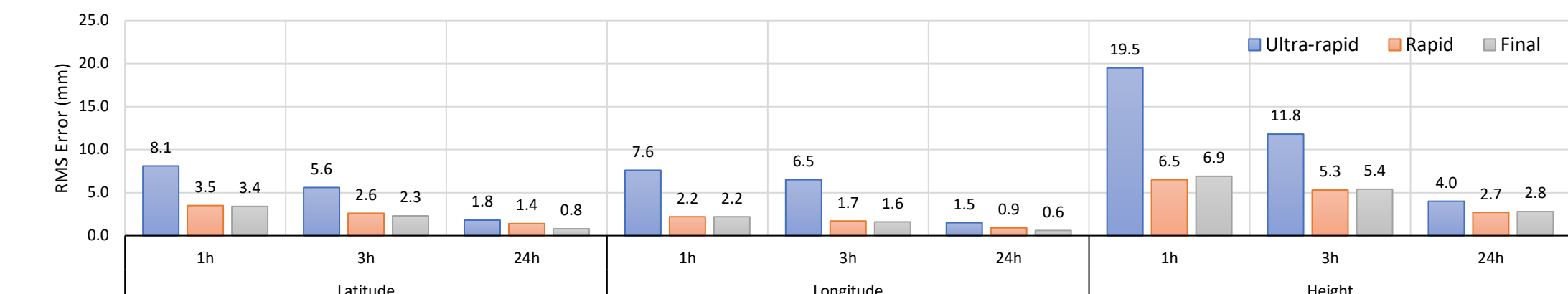
PRODUCTS USED IN CSRS-PPP V5

Three product lines enabling PPP-AR are used by CSRS-PPP: Ultra-rapid, Rapid, and Final

Product Line	GNSS	AR	Latency
Ultra-rapid	GR	G	~90 minutes after the hour
Rapid	GRE	GE	~18 hours after the end of the day
Finals	GRE	GE	12-15 days after the end of the week

Ultra-rapid products are generated by NRCan while Raps and Finals use the combined GPS orbits from IGS and an in-house satellite clock and bias combination using products enabling PPP-AR provided by various IGS analysis centers. Since operational IGS Rapid and Final products include only GPS products, GLONASS and Galileo products from the Center for Orbit Determination in Europe (CODE) are then incorporated into the combined GPS products to provide a multi-GNSS solution.

The following figure compares CSRS-PPP v5 Ultra-rapid, Rapid, and Final solutions in static mode for 1h, 3h, and 24h session lengths. Analysis is of static PPP solutions of 152 RINEX files from Canadian Active Control stations.



Final products used in CSRS-PPP depend on the observation date. Table 1 summarizes the products used, supported GNSS constellations, and PPP-AR availability.

Table 1: Final products used in CSRS-PPP (for data collected beginning 1 January 1995)

Start date	ITRF realization	Products used	GNSS	AR
1995-01-01	ITRF/IGSR3	IGS Repro3	GPS	None
2000-01-01	ITRF/IGSR3	IGS Repro3	GPS	GPS
2009-01-02	ITRF/IGSR3	IGS Repro3	GPS+GLO	GPS
2014-01-01	ITRF/IGSR3	IGS Repro3	GPS+GLO+GAL	GPS+GAL
2021-01-01	ITRF/IGSR3	IGS + NRCan Repro3*	GPS+GLO+GAL	GPS+GAL
2022-11-27	ITRF2020/IGS20	IGS Final + CODE GLO+GAL	GPS+GLO+GAL	GPS+GAL
2025-02-02	ITRF2020/IGb20	IGS Final + CODE GLO+GAL	GPS+GLO+GAL	GPS+GAL
2026-01-11	ITRF2020/IGc20	IGS Final + CODE GLO+GAL	GPS+GLO+GAL	GPS+GAL

*Combination of IGS Repro3 orbits and ERP's with NRCan in-house satellite clocks and biases enabling PPP-AR

EVALUATION OF IGS MULTI-GNSS DEMONSTRATION PRODUCTS

The recent IGS demonstration (DEM) products are combined multi-GNSS (GPS, Galileo, GLONASS) Final products, including orbits, clocks, biases, and reference attitudes generated using Geoscience Australia's ROCS orbit combination software, NRCan's SPARKCombo clock and bias combination software, and TU Graz's GROOPS software for reference attitudes. These products provide combined Galileo and GLONASS products beyond the Repro3 period, thus enabling full multi-GNSS PPP-AR. A test with CSRS-PPP was conducted to evaluate these products. GPS, GLONASS, and Galileo observations are processed with DEM products and results are compared to those of GPS-only IGS operational products and NRCan Final products used in CSRS-PPP.

A total of 99 IGS stations are used in this study, as shown in Figure 1. One day per week is processed between 30 November 2022 and 11 March 2026 (172 days). After quality control — considering rejections due to lack of observations or missing reference coordinates — a total of 15177 datasets are processed, with session lengths ranging from 15 minutes to 24 hours. Data is processed with CSRS-PPP with three product lines: IGS DEM, IGS OPS, and NRCan Finals. The performance achieved with the different products is then analyzed.

ACCURACY

Figure 2 compares the PPP results between IGS DEM, IGS OPS, and NRCan Finals in static mode for 24h session length. It shows the RMS errors computed from all 24h datasets, divided into Latitude, Longitude, and Height components. Since the IGS OPS includes only GPS and does not include satellite clock corrections and biases enabling PPP-AR, only GPS PPP in float mode is performed. PPP with ambiguity resolution (AR) is only attempted for GPS and Galileo with IGS DEM and NRCan Final products. **Results show comparable performance between IGS DEM and NRCan Final products, demonstrating the benefits of multi-GNSS and ambiguity resolution.**

CONVERGENCE

Figure 3 shows convergence improvements for short sessions (15 minutes to 3 hours). **Multi-GNSS DEM products significantly reduce PPP convergence time** compared to GPS-only IGS OPS solutions. Sub-centimetre horizontal accuracy can be achieved within approximately one hour thanks to multi-GNSS products and ambiguity resolution.

Figure 1: Stations used for IGS DEM product evaluation

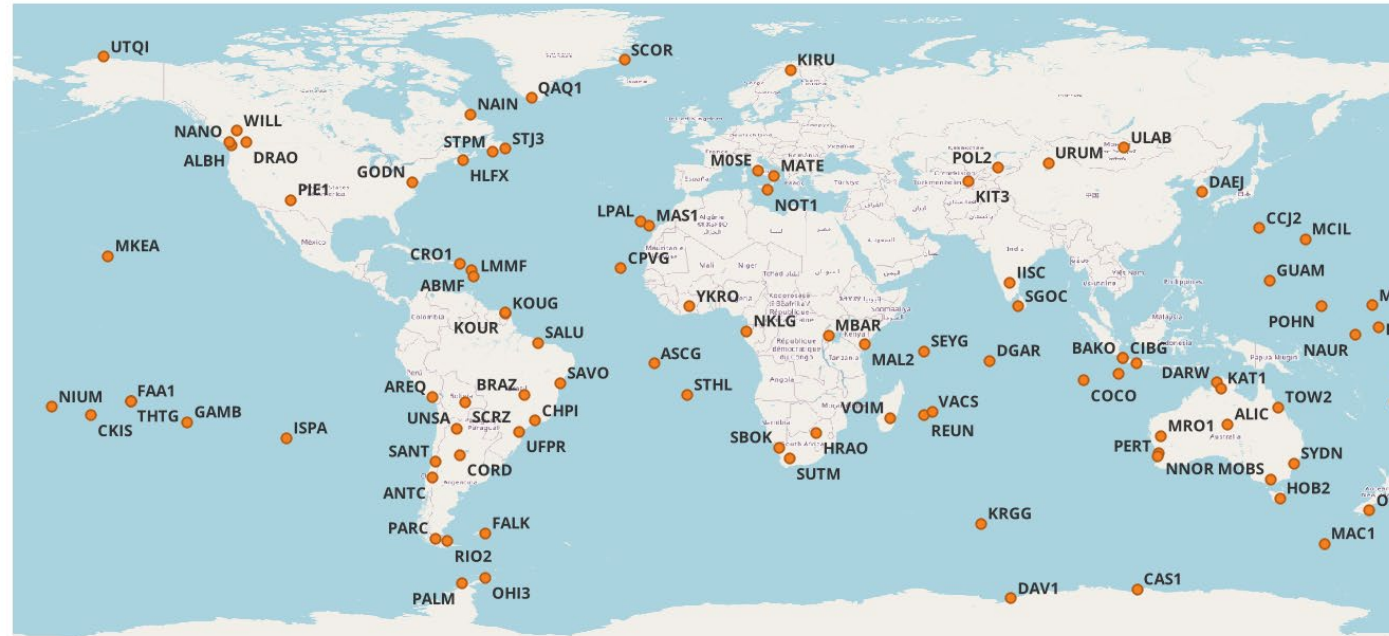


Figure 2: Comparison between CSRS-PPP results with IGS DEM, IGS OPS, and NRCan Finals

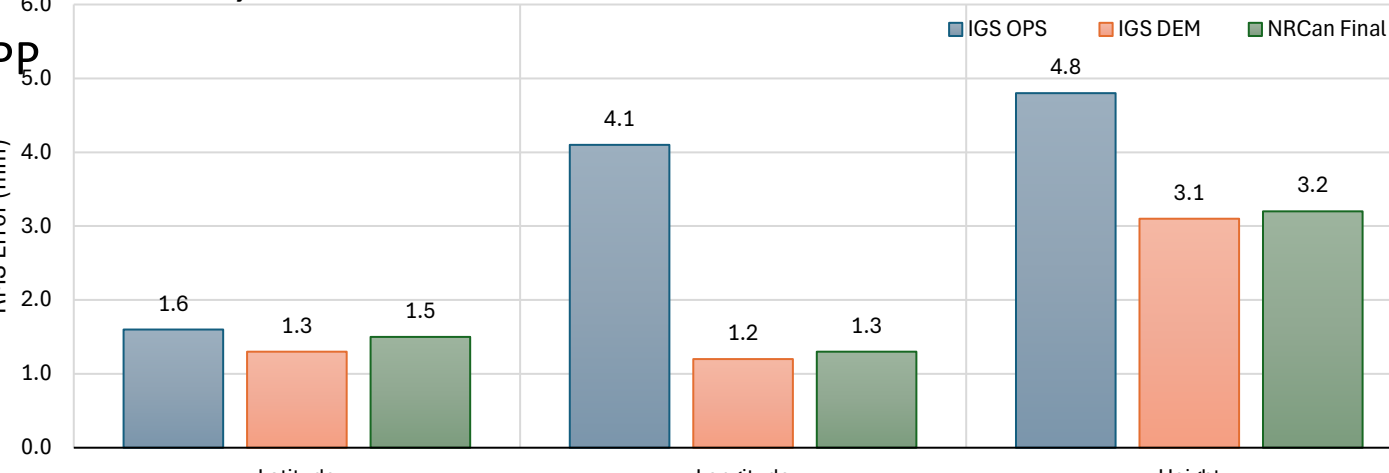
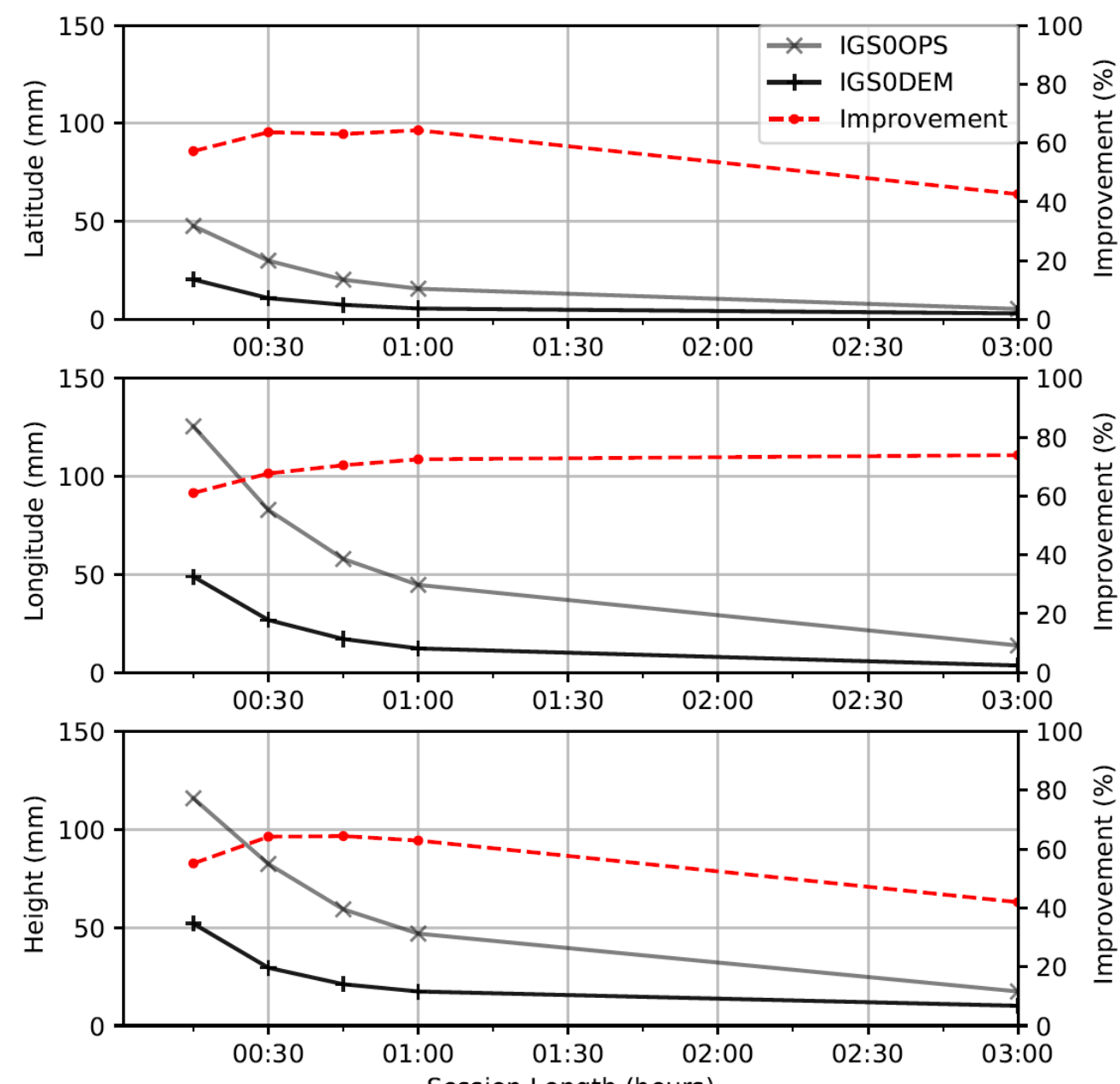


Figure 3: Convergence of PPP solutions for short sessions

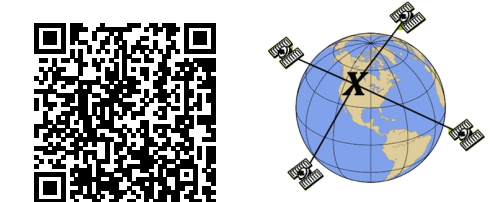


CONCLUSIONS

NRCan's CSRS-PPP service has provided efficient and accurate positioning to a broad range of users since 2003 through the use of precise IGS and NRCan products. The recent support for Galileo observations has improved positioning accuracy and reduced convergence time, although it currently relies on products from multiple sources. The development of consistent IGS multi-GNSS combined products would provide a unified solution for CSRS-PPP and further strengthen the value and interoperability of both IGS products and the CSRS-PPP service. Evaluation of the IGS multi-GNSS Demonstration (DEM) products shows clear benefits for PPP applications:

- Multi-GNSS processing (GPS, Galileo, and GLONASS) combined with ambiguity resolution significantly improves positioning accuracy and convergence performance.
 - DEM products achieve performance comparable to NRCan Final products and outperform GPS-only IGS operational solutions.
 - Sub-centimetre horizontal accuracy can be achieved within one hour, demonstrating the benefits of combined constellations and consistent bias products.
 - The availability of extended multi-GNSS products beyond the Repro3 period further improves long-term PPP consistency and capability.
- These results strongly support the transition of IGS multi-GNSS combined products from demonstration to fully operational status.**

CSRS-PPP landing page:



For further information:
geodeticinformation-information@geodesique@nrcan-nrcan.gc.ca



**ABSTRACT
ID 6952**