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Next-Generation GNSS Precise Orbit Determination Software for the EMR Analysis Center

Authors: S. BANVILLE, E. MAIA, T. NIKOLAIDOU, O. KAMALI, P. LAMOTHE, Z. BARDOSSY
Canadian Geodetic Survey, Natural Resources Canada

IGS 2026 WORKSHOP
SANTIAGO DE CHILE
33°26' S 70°39' O

INTRODUCTION

The Canadian Geodetic Survey (CGS) of Natural Resources Canada (NRCan) operates the EMR Analysis Centre within the International GNSS Service (IGS). Since the 1990s, CGS has contributed precise GNSS products to the IGS using third-party software such as Bernese and GIPSY-OASIS/GIPSY-X (Nikolaidou et al. 2024). To develop sovereign GNSS expertise, CGS is investing in the development of an in-house precise orbit determination (POD) software. This initiative aims to strengthen independent GNSS analysis capabilities while providing a flexible framework for testing alternative models and supporting future GNSS constellations. This poster presents preliminary results from the software, which is currently under active validation. These results provide a first indication of the performance of the new software and highlight areas requiring further refinement. In the figures and tables, these solutions are labeled as EMR; however, they should not be confused with the operational EMR products, which are not included in this study. All solutions considered herein are "final" products in which station coordinates are freely estimated.

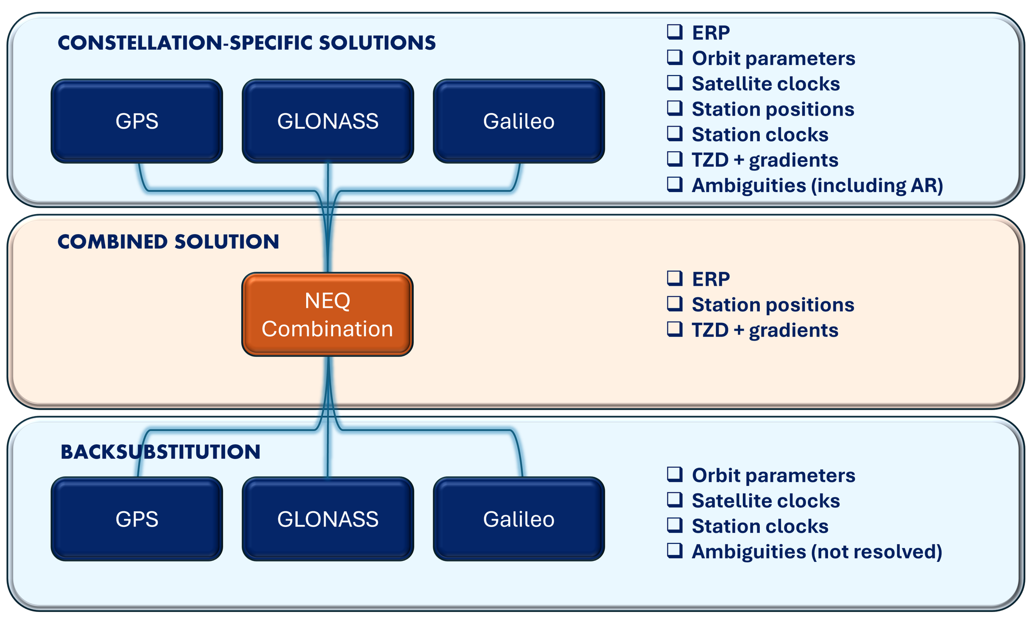
SOFTWARE DESCRIPTION

The software implements a full dynamical precise orbit determination (POD) approach consistent with IGS standards. Orbit and clock parameters are estimated from undifferenced GNSS observations, with support for current and future multi-GNSS constellations. A decoupled clock model, based on an ambiguity datum, enables parameter estimation using carrier-phase observations only. Additional geometry-free linear combinations are processed independently to estimate observable-specific code and phase biases.

Computational efficiency is achieved through an initial constellation-wise processing strategy, enabling parallel execution. As a result, processing multiple constellations requires approximately the same time as a single-constellation solution. Parameters common to all constellations are subsequently combined at the normal equation (NEQ) level to ensure consistency, a step that requires only a few seconds.

Using these updated parameters, back-substitution is applied to recover the optimal estimates for constellation-specific parameters.

Solar radiation pressure modeling uses the "Rock 'n Roll" (RnR25) model developed by Dilsner and Springer (2025). Residual errors are absorbed by a 5-parameter version of the ECOM model (D0, Y0, B0, B2S, B2C).

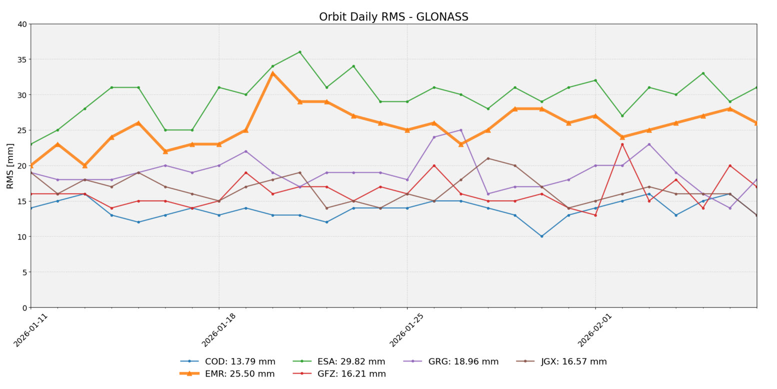


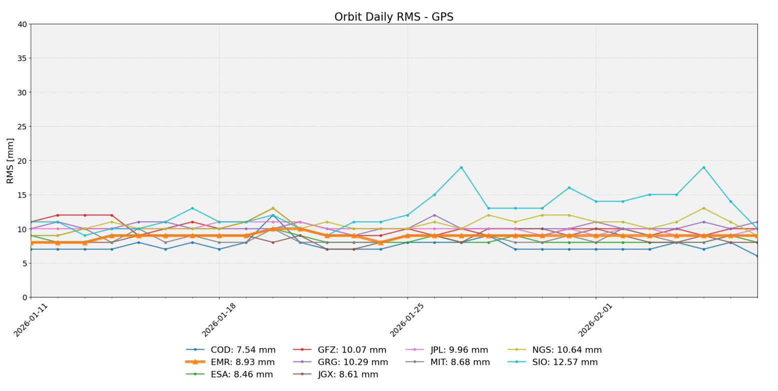
Parameters	Description
Software	NRCan's SPARKPod (orbit modelling) and SPARKNet (network adjustment)
Session duration	24 hours
Observations	Dual-frequency (GPS: L1/L2, GLONASS: L1/L2, Galileo: E1/E5a), 30 sec, cutoff 7.5 deg
EOP	Apriori: Bulletin A / Estimation: daily values + rates
Satellite orbits	Apriori: IGS broadcast (BRDC00IGS) Estimation: initial position, velocity and SRP
Gravity model	EGM2008, degree/order 12
Solar radiation pressure	Apriori: RnR25 (Dilsner and Springer, 2025) Estimation: ECOM-5 (D0,Y0,B0,B2S,B2C)
Station positions	Apriori: propagated IGc20 or latest weekly solution Estimation: NNR + NNT constraints
Troposphere	Apriori: VMF1 Estimation: TZD: piecewise linear (1h) , gradients: piecewise linear (12h)
Ionosphere	2nd order corrected using EMR final GIM
Earth tides	IERS2010
Ocean tides	FES2014b
Pole tides	IERS2010 / Desai-Sibois subdaily EOP
Atmospheric tides	Not applied

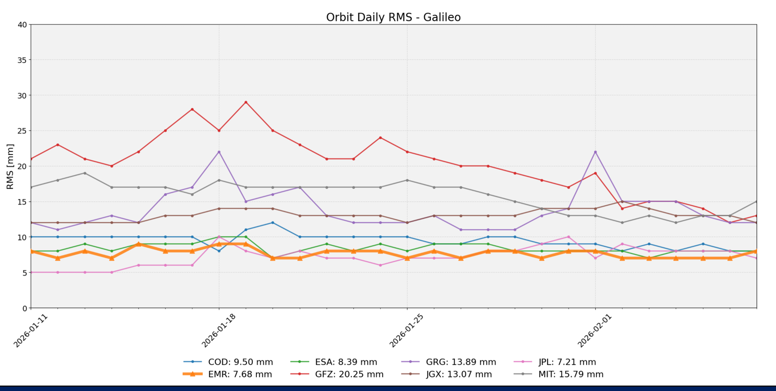
PRELIMINARY RESULTS

ORBITS

Daily orbit combinations were generated using the Robust Orbit Combination Software (ROCS) (Zajdel et al., 2023). The plots present the daily and mean RMS errors for all analysis center (AC) operational final (OPSFIN) solutions. The new EMR orbit solutions show good agreement with other ACs for GPS and Galileo. However, further improvements are required for GLONASS.

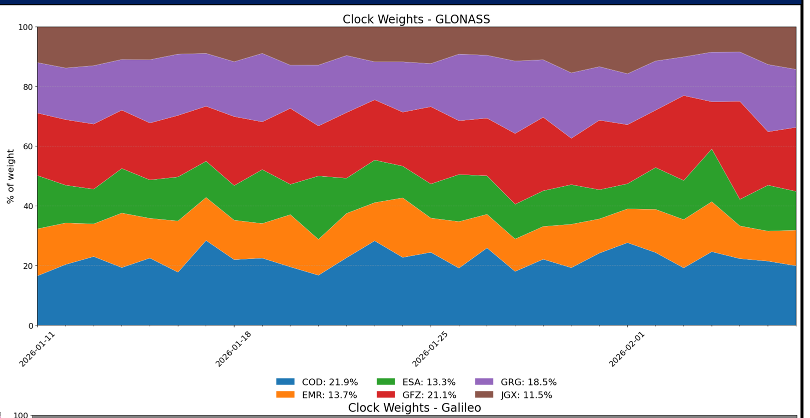


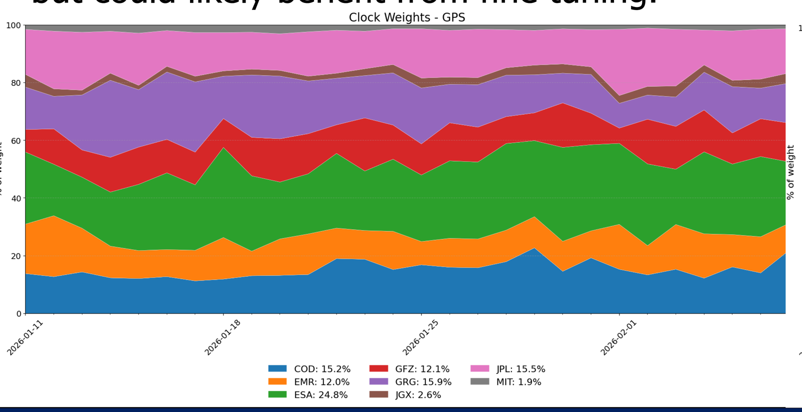


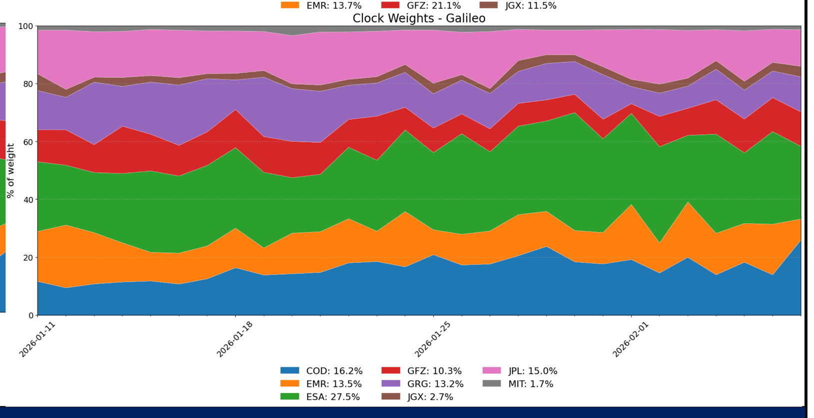


SATELLITE CLOCKS

Daily clock combinations were generated using the SPARKCombo software (Banville et al., 2020). The plots present the daily and mean weights assigned to each analysis center (AC) solution across all processed constellations. The results indicate that the clock estimates produced by the new software are of comparable precision to those from other ACs but could likely benefit from fine tuning.



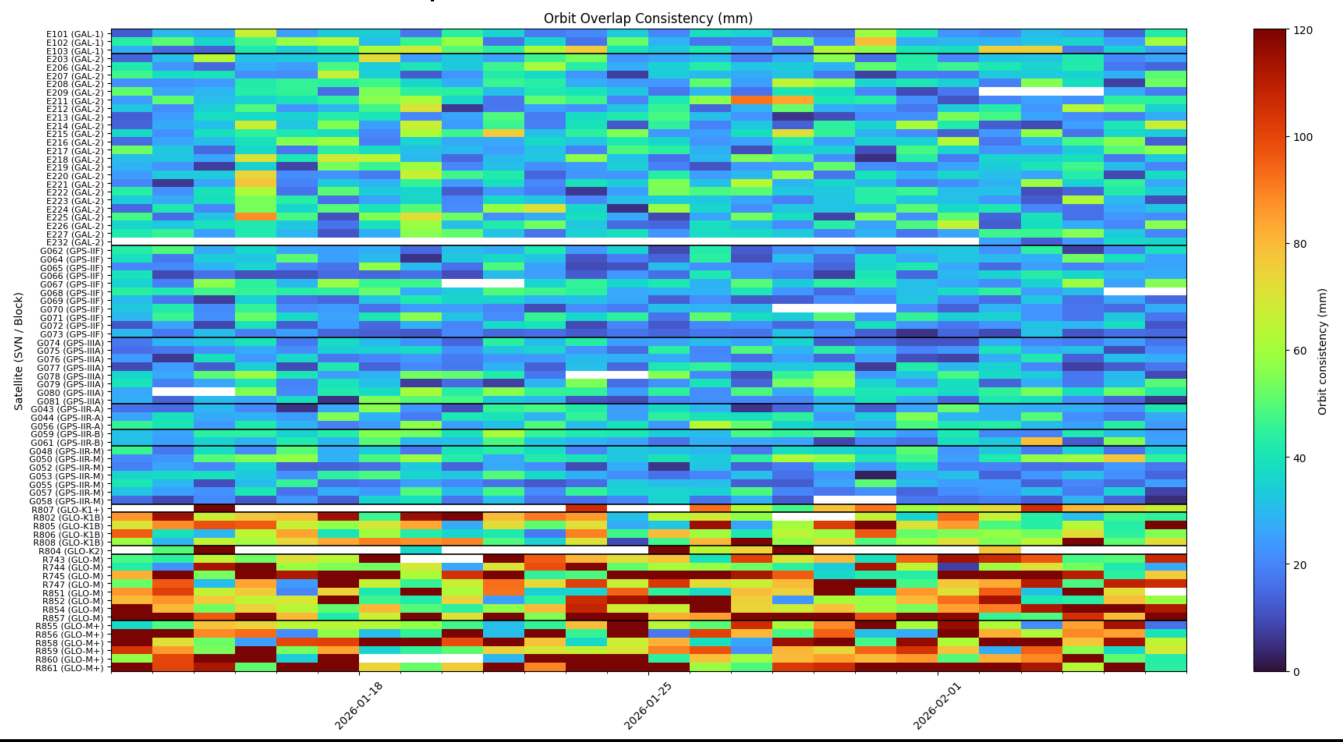




ORBIT OVERLAPS

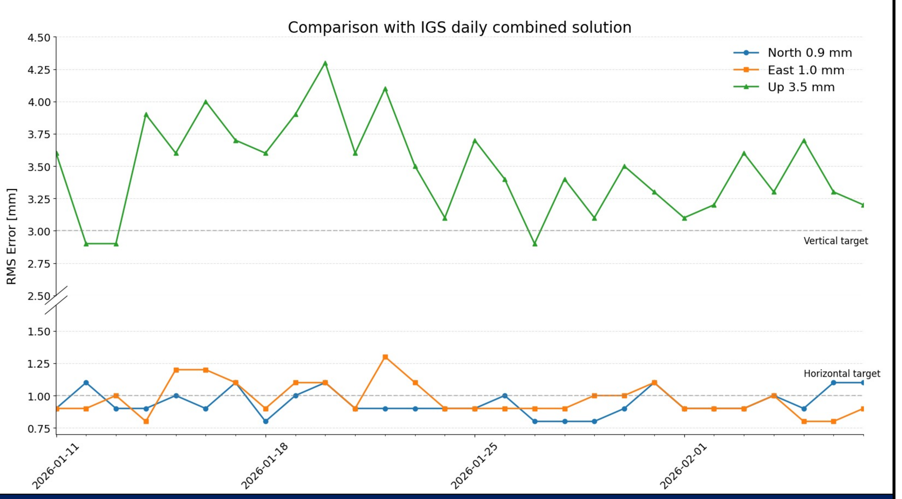
With 24-hour sessions, orbit determination is independent from day to day. This allows the midnight epoch between consecutive sessions to be used to validate 3D orbit overlaps for all satellites. The results, shown in the accompanying table and figure, indicate overlaps at the ~3 cm level for GPS and Galileo, with no clear differences among block types. Larger discrepancies are observed for GLONASS, with overlaps of approximately 8 cm, indicating modeling deficiencies. Processing longer sessions (e.g., 30 hours) would reduce these overlaps.

Block	Mean Overlap [mm]
GAL 1	34.0
GAL 2	32.6
GLO K1+	78.7
GLO K1B	63.8
GLO K2	76.3
GLO M	76.1
GLO M+	80.0
GPS IIF	26.0
GPS IIIA	27.5
GPS IIR-A	28.9
GPS IIR-B	32.3
GPS IIR-M	26.3



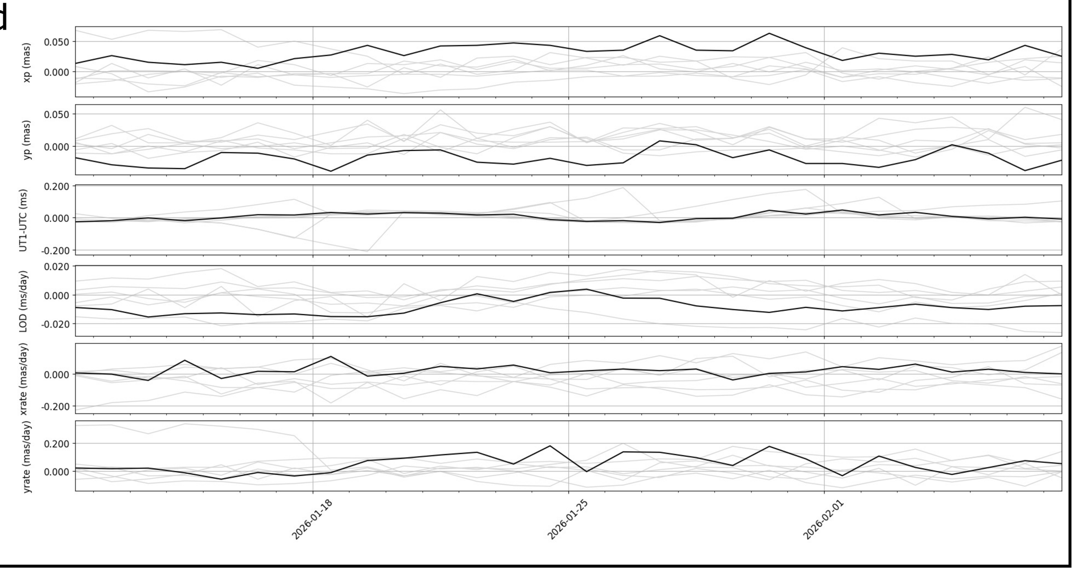
STATION POSITIONS

Estimated positions for the 100 stations included in the adjustment are compared with the IGS daily combined solutions after applying a 7-parameter Helmert transformation. The RMS errors indicate good agreement in the horizontal components, while the vertical component still exhibits slightly larger-than-expected discrepancies. Tropospheric mismodeling for equatorial stations seems to be a contributing factor.



EARTH ROTATION PARAMETERS

Estimated Earth rotation parameters (ERP) are compared with the IGS combined values. The solutions obtained with the new software are shown in black, while results from other analysis centers (ACs) are displayed in light gray for reference. The comparison indicates a systematic pattern over this period, with x-pole estimates generally larger than those of other ACs, and y-pole estimates generally smaller.



CONCLUSIONS

Preliminary multi-GNSS solutions generated with the next-generation EMR POD software demonstrate promising performance. Orbit solutions for GPS and Galileo are comparable to those of other analysis centers. However, GLONASS orbit modeling requires further investigation, as larger orbit overlaps confirm remaining deficiencies, likely related to solar radiation pressure modeling. The weights assigned to EMR satellite clock estimates in the combination are slightly lower than those from operational solutions, pointing to residual inconsistencies. Horizontal station position errors are at the 1 mm level, while vertical errors exceed the expected 3 mm RMS on several days and require further analysis. Earth orientation parameters exhibit systematic biases over the analyzed period; longer time series will be required to better understand their origin. Ongoing efforts aim to resolve these issues, with contributions from the new software to the IGS anticipated by the end of 2026.

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ABSTRACT ID 6953