GeoNOVA

Nova Scotia Coordinate Referencing Program

Yearly Update

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Senior Program Administrator Officer

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NSACS Updates

- Purchase of additional 6 Septentrio PolaRX5 receivers to make a total of 17 new receivers.
- Installation of 14 of the 17 new receivers at various locations throughout Nova Scotia.
- Spring 2025 adjustment should add approximately 120+ new NSHPNs to the existing network.
- All service providers are receiving full 4 constellation raw GNSS data at new NSACS sites.
- Upgrades to current modems to 5G capabilities.

Geo++®

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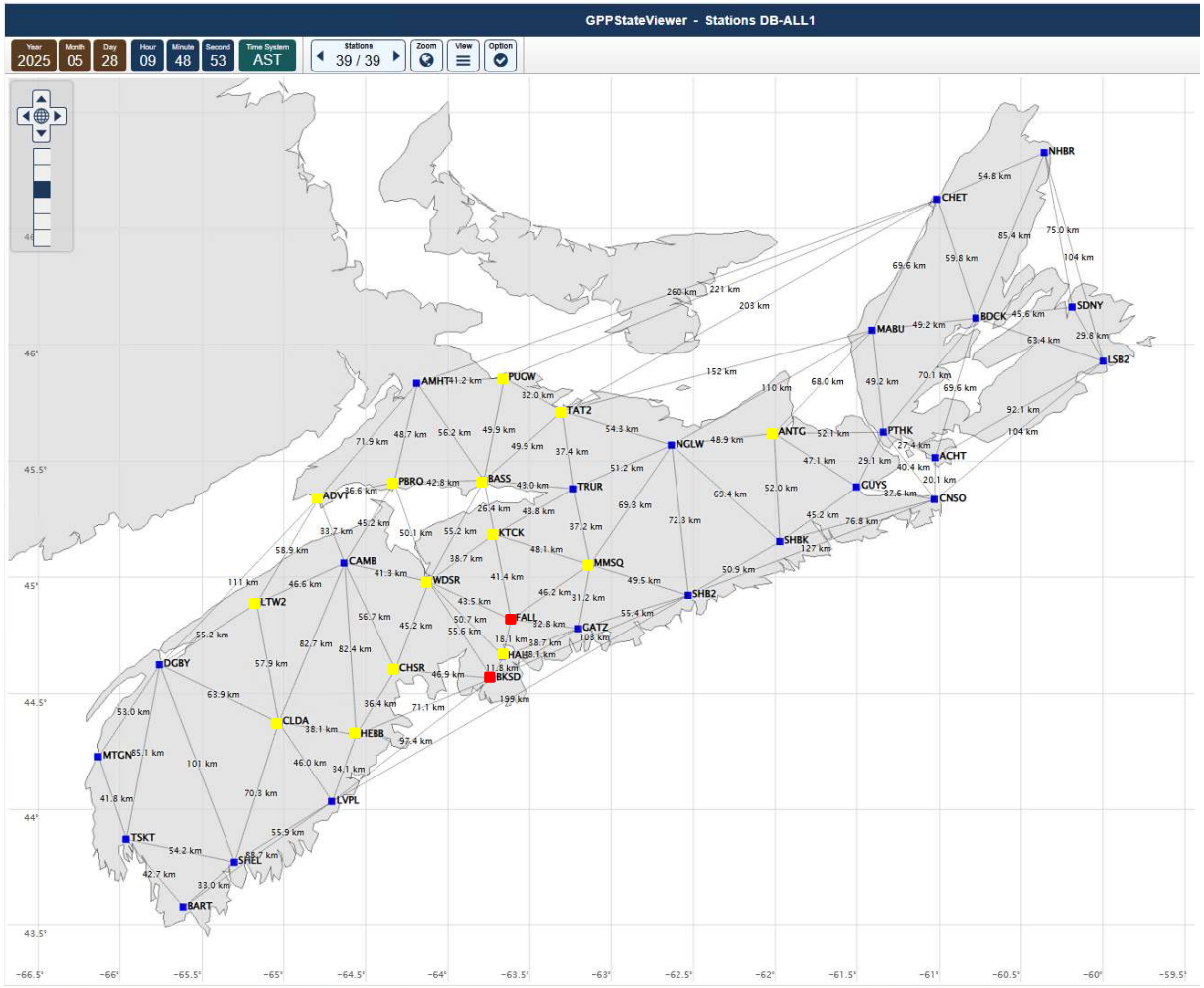
Nova Scotia Active Control Stations

- 23X Trimble NetR9 (3.5 GNSS)
- 14X Septentrio PolaRX5 (4 GNSS)
- 2X Trimble Alloy (4 GNSS)

*2X Septentrio PolaRX5 Spares



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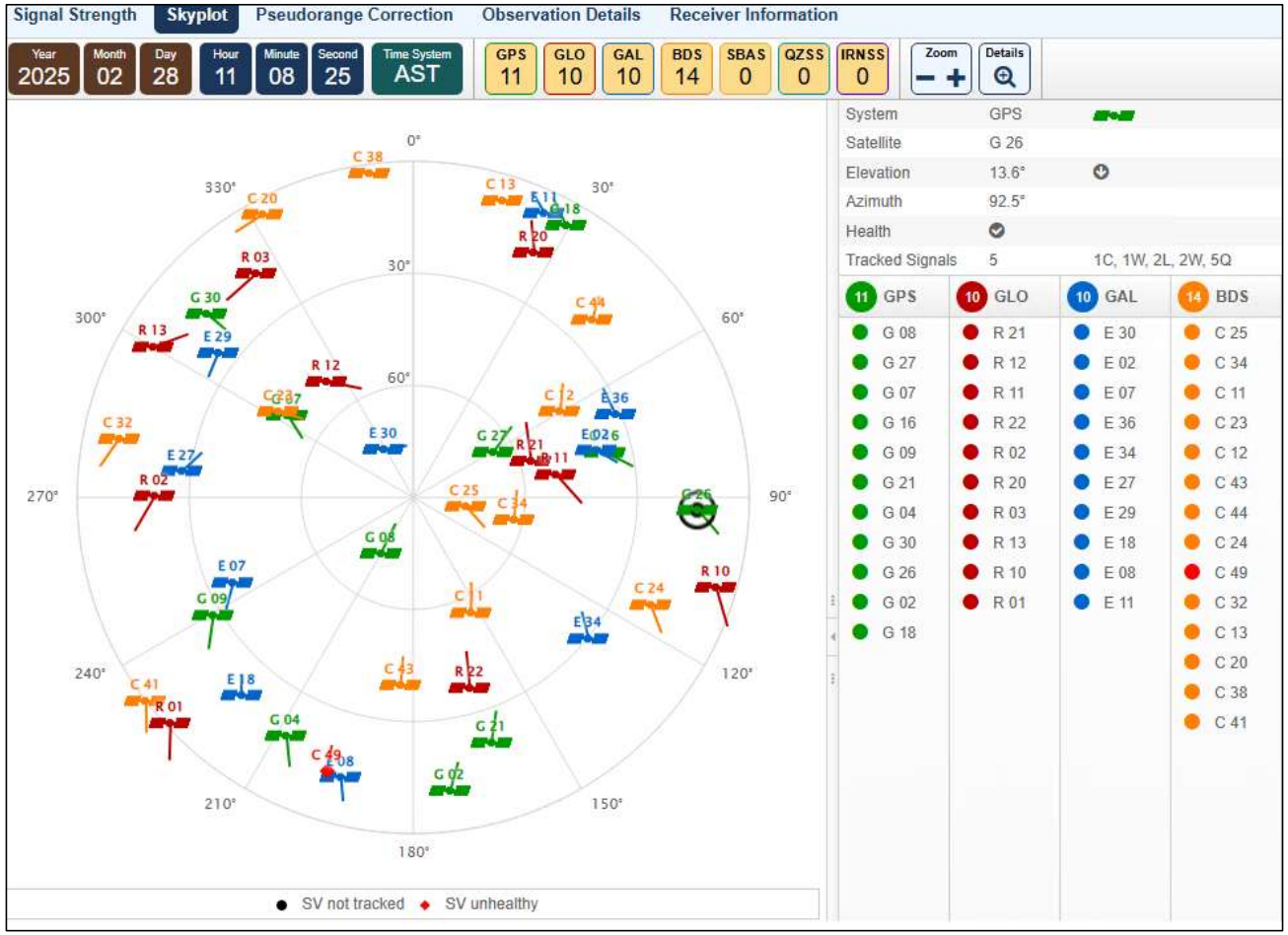
GNSS Satellites at HALI



11 GPS
10 GLONASS
10 GALILEO
14 BeiDou

Total: 45 satellites

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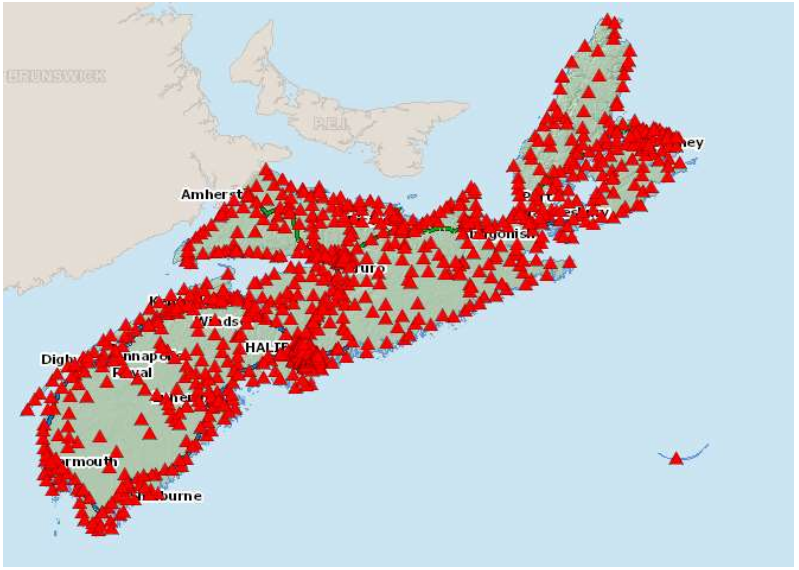
NSHPN Adjustments

- Used to upgrade former NSCCS (ATS77) monuments to NSHPN (NAD83(CSRS)2010.0 v6)

- Spring 2024 adjustment is the most recent and data has been updated on the Coordinate Reverencing Viewer.

- Spring 2025 adjustment should add approximately 100+ new NSHPNs to the existing network.

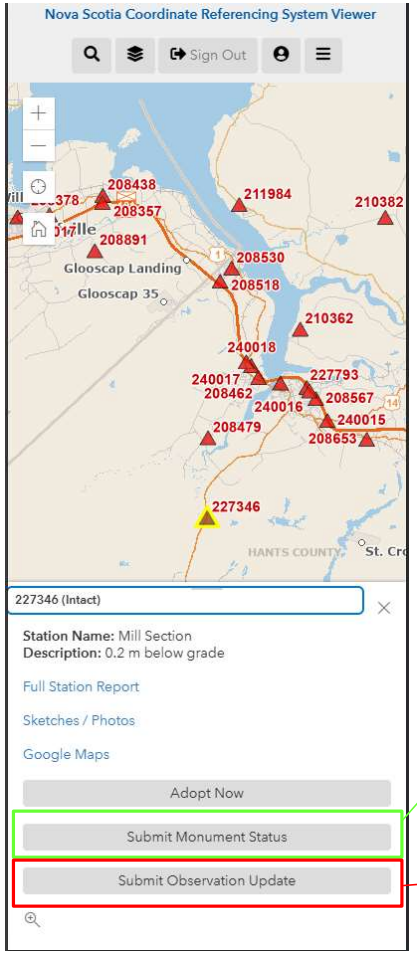
- Observations came primarily from municipal and government surveyors

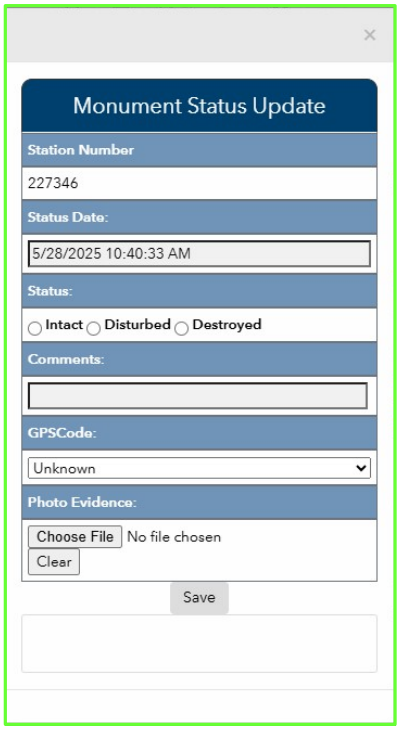


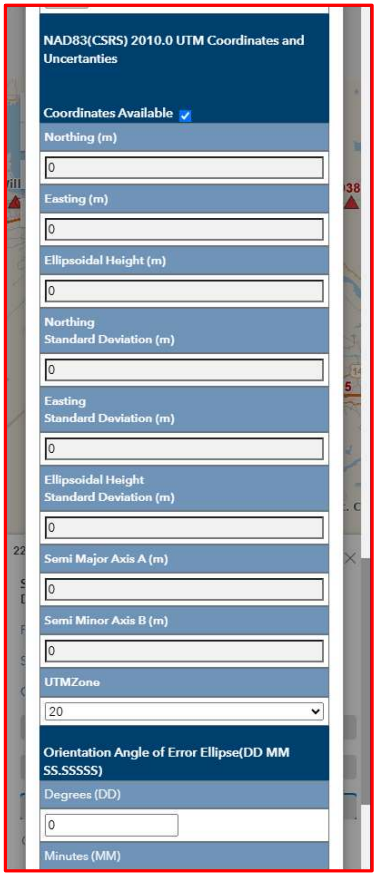
Good Photos

Bad Photos

Mobile Coordinate Referencing Viewer







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GATZ NSACS Move

GATZ NSACS Move (con't)

- Installation of equipment in June/July 2025
- Requires 3 months minimum GNSS observations
- Expecting to have online in late 2025

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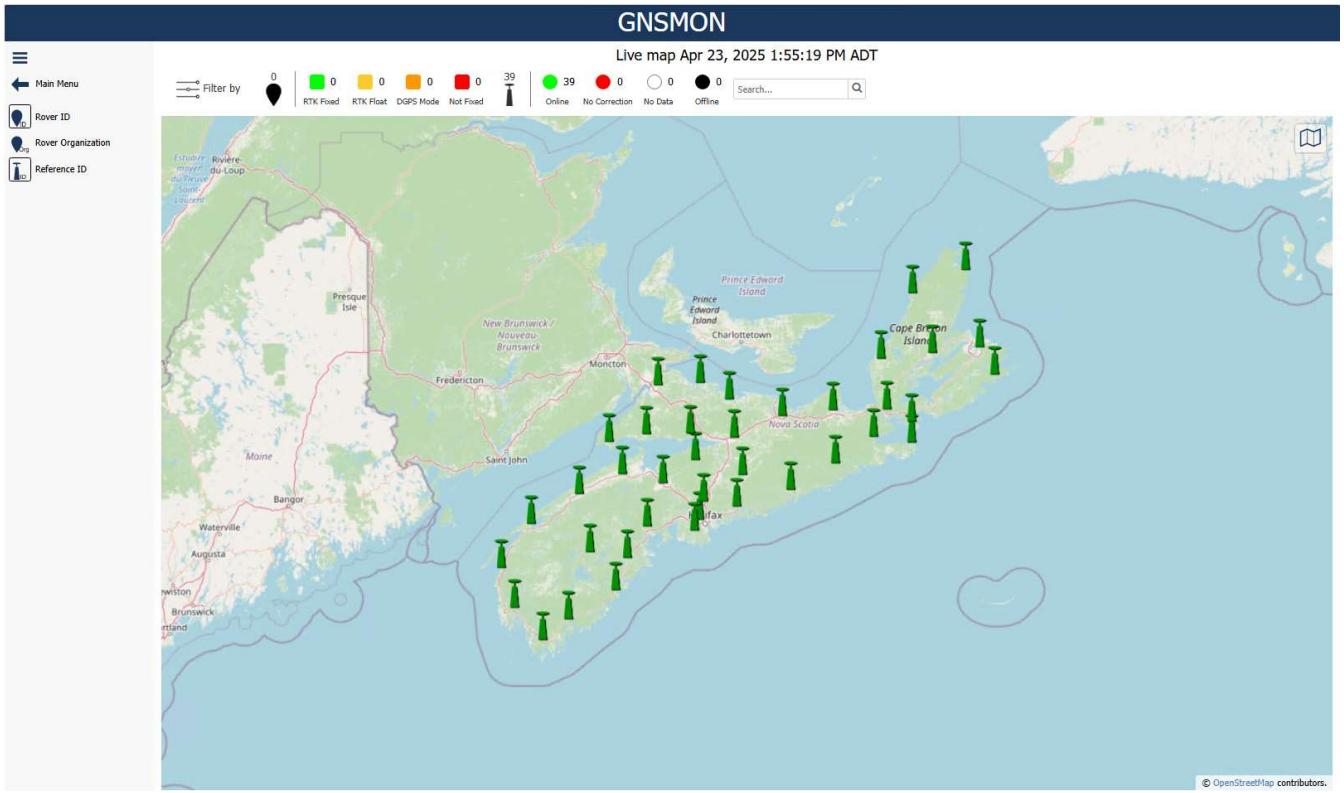
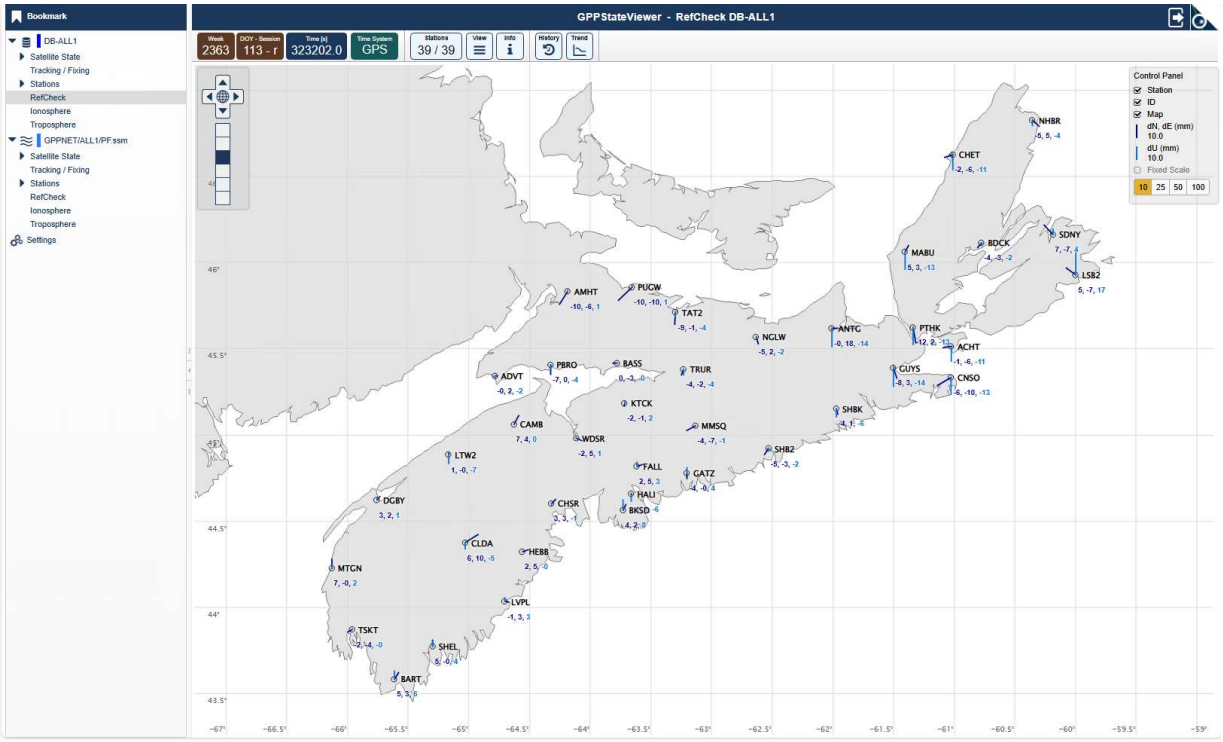
GNSMART Application (GEO++)



- Purchased via RFP at the end of the 2024 fiscal year
- Will allow us to end the contract with Trimble and administer the data and GNS subscriptions
- Allow GNS to intervene software when issues arrive and not rely on outside company to fix/repair
- Allow us to attract new subscribers of Raw GNSS data
- Unlimited GNS user accounts

GNSMART Features



- Real time ability to monitor the overall quality and precision of each NSACS station
- Allows for future proof solution for all existing and future GNSS constellations to be integrated and not limited to specific equipment manufacturers.
- Allows for multipath reduction at each NSACS site based on seasonal changes (tree canopy) and building geometry.
- Corrects for antenna manufacturer bias, ionospheric/tropospheric changes, receiver manufacturer bias, ocean loading, etc.

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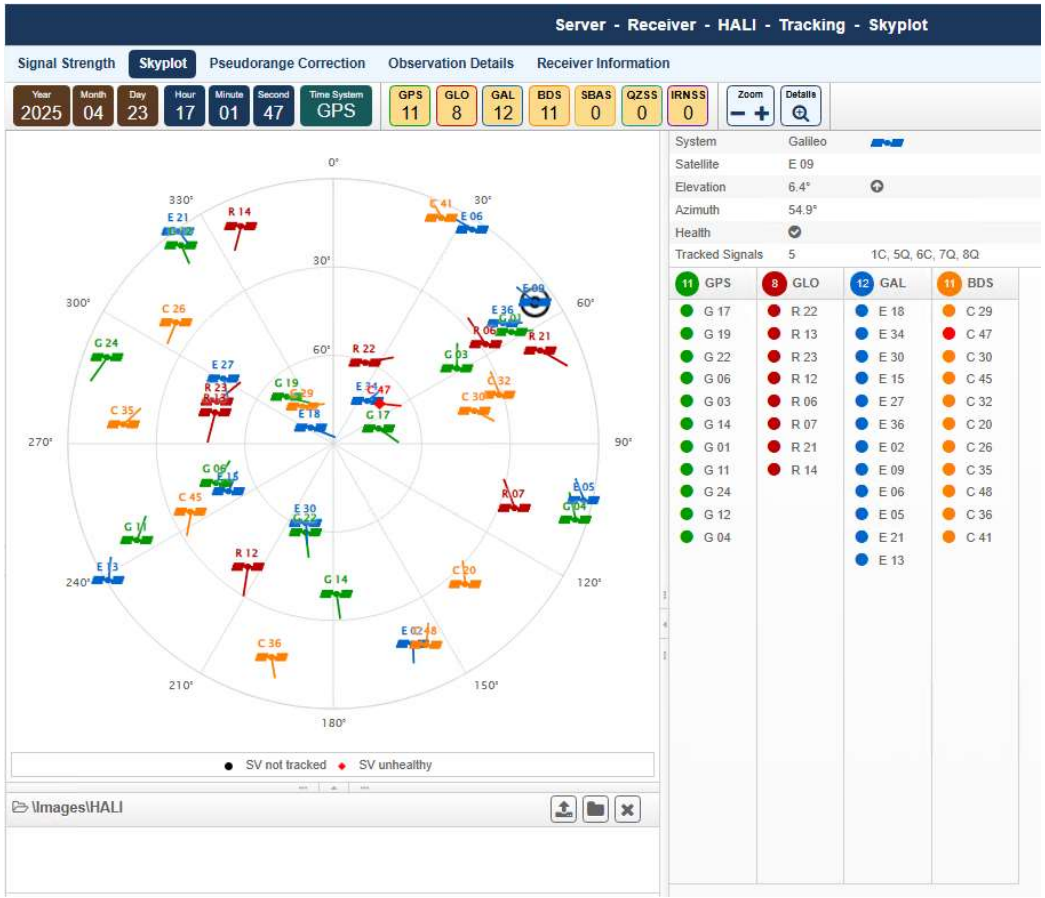
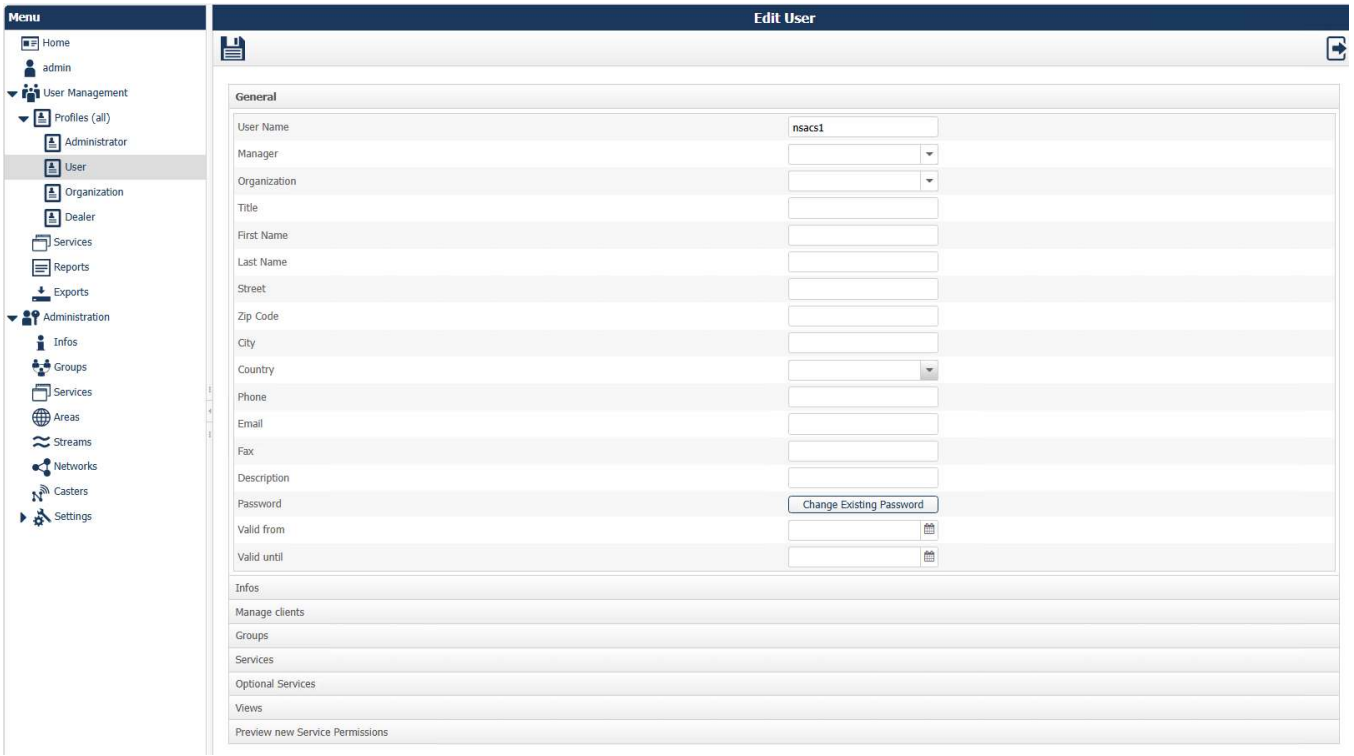
GNSMART Functionality and Flexibility

- Currently able to receive and transmit raw GNSS data from 4 constellations : GPS, GLONASS, Galileo and BeiDou.
- Currently seeing on average 42 satellites per station and upwards of 50 at a time.
- Provides a Single Baseline, VRS or MAC solution to NRTK users depending on their preference
- Ability to run multiple mountpoints using different coordinate systems



NRTK Subscriptions

- Subscriptions will now be administered by GeoNova within the Government of Nova Scotia by submitting a help desk ticket.
- All existing subscriptions for government users will be replaced with new subscriptions for the new system/software.
- Will still require a username and password. Instructions will be provided for setup.
- Multiple RTCM mountpoints depending on what system the user requires.



GNSMART User Tools

- Users will have the ability to download RINEX data for NSACS sites for post-processing kinematic or static baselines using user supplied software.
- VRS post processing solutions will be available via user portal where RINEX file is submitted and calculated position is provided as an output.
- Users will also be able to login to the GeoNova website to see the real time status of each NSACS.

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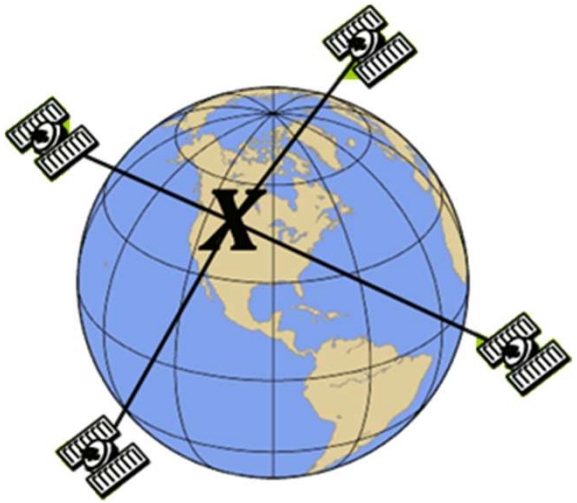
Overview



CSRS-PPP was upgraded from v4 to v5 on **14 May 2025** This upgrade includes:

- Support for Galileo PPP-AR for E1/E5a observations collected beginning **27 November 2022** and processed with **Rapid** or **Final** products
- Observations collected prior to 27 November 2022 will continue to be processed with legacy Finals supporting only GPS and GLONASS
- The Ultra-rapid products will also continue to support only GPS and GLONASS

CSRS-PPP Modernization – Products

- Daily Rapid Processes
  - Use IGS combined GPS orbits
  - Run a GPS in-house clock and phase bias combination
  - Add CODE satellite attitudes and IGS combined ERP's
  - Merge CODE GLO/GAL orbits, clocks, and GAL biases
  - Estimate satellite clock Allan Deviations (for high-rate kin jobs)
  - Run PPP process on current and previous day to estimate day-boundary-discontinuities (DBD's)

```
EMR0MGARAP_20250810000_01D_01D_ADV.ADV.gz
EMR0MGARAP_20250810000_01D_01D_OBD.BIA.gz
EMR0MGARAP_20250810000_01D_01D_ERP.ERP.gz
EMR0MGARAP_20250810000_01D_01D_OSB.BIA.gz
EMR0MGARAP_20250810000_01D_05M_ORB.SP3.gz
EMR0MGARAP_20250810000_01D_30S_ATT.OBX.gz
EMR0MGARAP_20250810000_01D_30S_CLK.CLK.gz
```

- Weekly Final Processes
  - Run 7 daily Finals using process above
- Final Reprocessing
  - Ran daily Finals from November 2022 to current using process above

Notes:

- Modernized Rapid products are available ~17:45ut vs ~09:30ut for our current Bernese Rapids
- CODE – Center for Orbit Determination in Europe (IGS Analysis Center which provides products for Bernese software users)

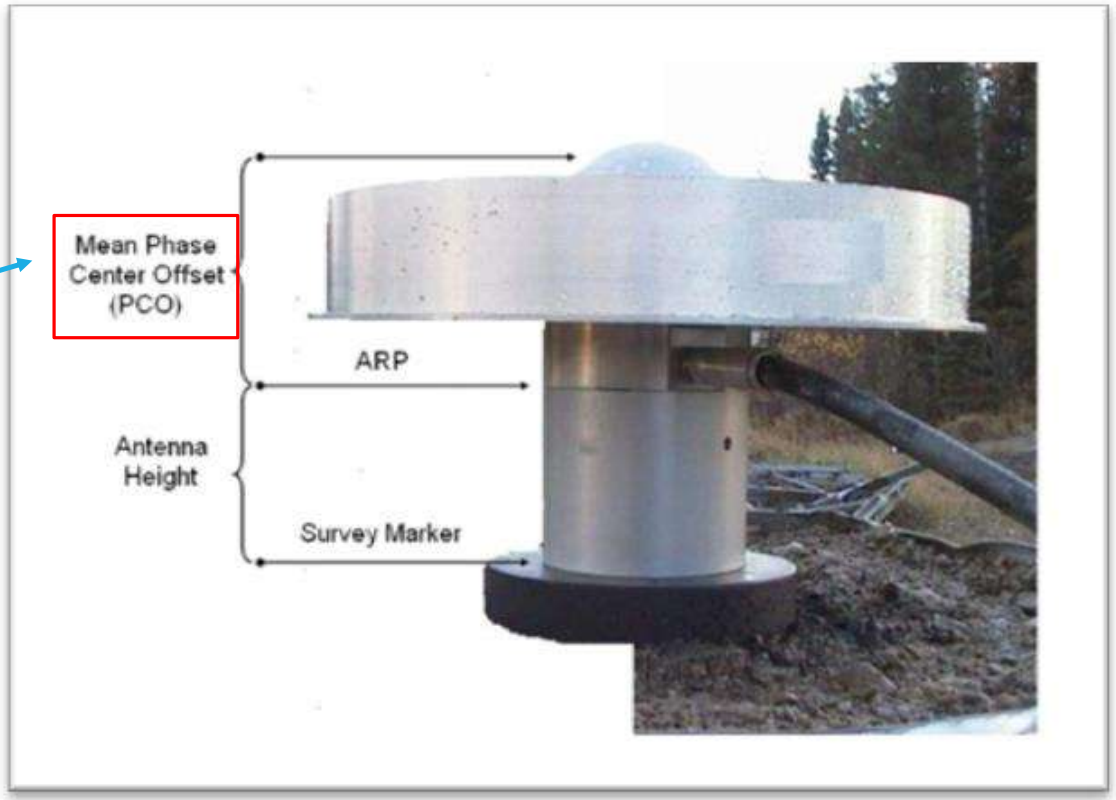
CSRS-PPP v5 updates

- New Rapid and Final product lines supporting Galileo
- PPP software updated from SPARK v4.16.0 to v5.11.0 enabling:
  - Estimation of relative antenna Phase Centre Offsets (PCO) and Phase Centre Variations (PCV) for antennas without full multi-GNSS absolute PCO/PCV calibrations

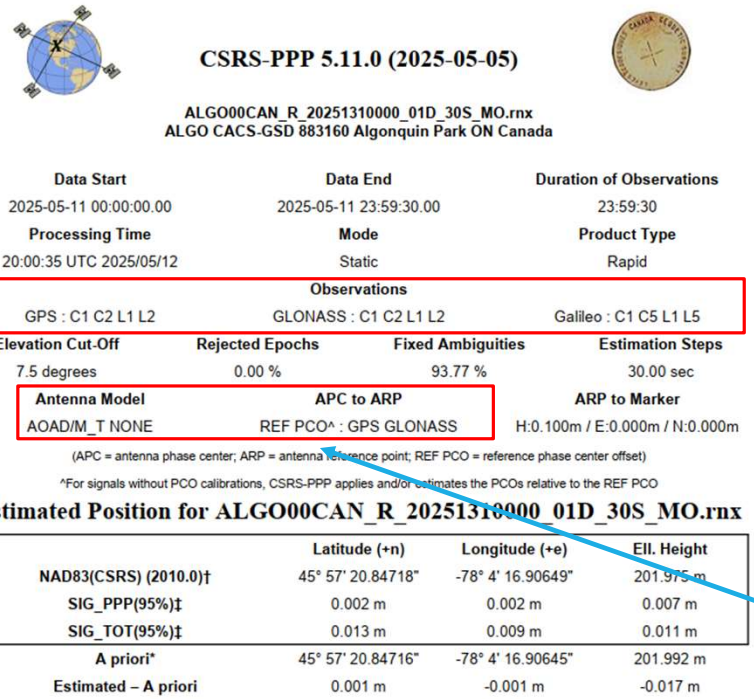
    (see next slide for details on PCO calibrations)
  - Fixing of day-boundary discontinuities in integer satellite clocks using an in-house estimated bias SINEX product
  - Application of 2nd order Ionosphere correction with Rapid and Final products
  - Correction for antennas not oriented north when the azimuthal offset is provided in the RINEX header
  - Application of satellite attitude quaternions in ORBEX format
- Other service updates
  - Improved warning messages
  - Updated ANTEX handling to ensure consistent handling between PPP and products
  - Simplified post processing strategy
  - Improved reporting and documentation

GNSS antenna reference point vs antenna phase center

- IGS/NGS provide the PCOs (and variations by elevation/azimuth) for many antenna types
- PCOs are frequency dependant and can vary between constellations



PDF report updates



CSRS-PPP 5.11.0 (2025-05-05)

ALGO00CAN_R_20251310000_01D_30S_MO.rnx
ALGO CACS-GSD 883160 Algonquin Park ON Canada

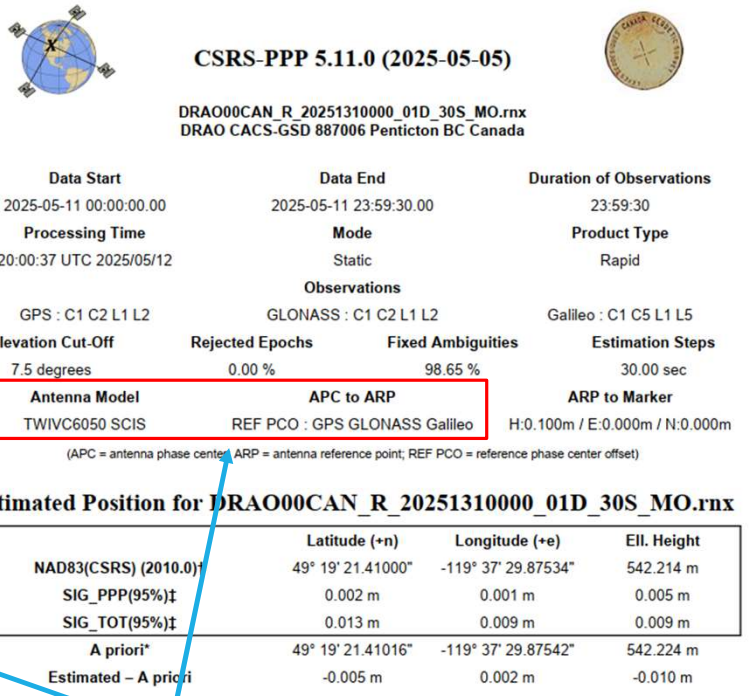
Data Start	Data End	Duration of Observations
2025-05-11 00:00:00.00	2025-05-11 23:59:30.00	23:59:30
Processing Time	**Mode**	**Product Type**
20:00:35 UTC 2025/05/12	Static	Rapid
	Observations	
GPS : C1 C2 L1 L2	GLONASS : C1 C2 L1 L2	Galileo : C1 C5 L1 L5
Elevation Cut-Off	**Rejected Epochs**	**Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 %	93.77 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
AOAD/M_T NONE	REF PCO^ : GPS GLONASS	H:0.100m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point; REF PCO = reference phase center offset)

^For signals without PCO calibrations, CSRS-PPP applies and/or estimates the PCOs relative to the REF PCO

Estimated Position for ALGO00CAN_R_20251310000_01D_30S_MO.rnx

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2010.0)†	45° 57' 20.84718"	-78° 4' 16.90649"	201.975 m
SIG_PPP(95%)‡	0.002 m	0.002 m	0.007 m
SIG_TOT(95%)‡	0.013 m	0.009 m	0.011 m
A priori*	45° 57' 20.84716"	-78° 4' 16.90645"	201.992 m
Estimated – A priori	0.001 m	-0.001 m	-0.017 m



CSRS-PPP 5.11.0 (2025-05-05)

DRAO00CAN_R_20251310000_01D_30S_MO.rnx
DRAO CACS-GSD 887006 Penticton BC Canada

Data Start	Data End	Duration of Observations
2025-05-11 00:00:00.00	2025-05-11 23:59:30.00	23:59:30
Processing Time	**Mode**	**Product Type**
20:00:37 UTC 2025/05/12	Static	Rapid
	Observations	
GPS : C1 C2 L1 L2	GLONASS : C1 C2 L1 L2	Galileo : C1 C5 L1 L5
Elevation Cut-Off	**Rejected Epochs**	**Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 %	98.65 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
TWIVC6050 SCIS	REF PCO : GPS GLONASS Galileo	H:0.100m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point; REF PCO = reference phase center offset)

Estimated Position for DRAO00CAN_R_20251310000_01D_30S_MO.rnx

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2010.0)†	49° 19' 21.41000"	-119° 37' 29.87534"	542.214 m
SIG_PPP(95%)‡	0.002 m	0.001 m	0.005 m
SIG_TOT(95%)‡	0.013 m	0.009 m	0.009 m
A priori*	49° 19' 21.41016"	-119° 37' 29.87542"	542.224 m
Estimated – A priori	-0.005 m	0.002 m	-0.010 m

Updated *Observations* block

Updated *APC to ARP* block

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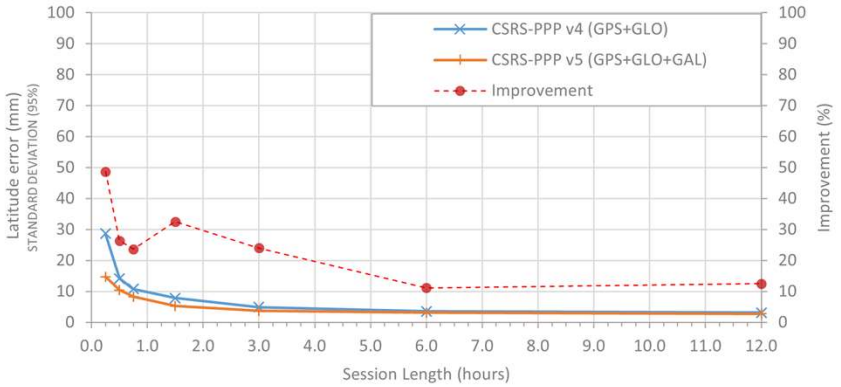
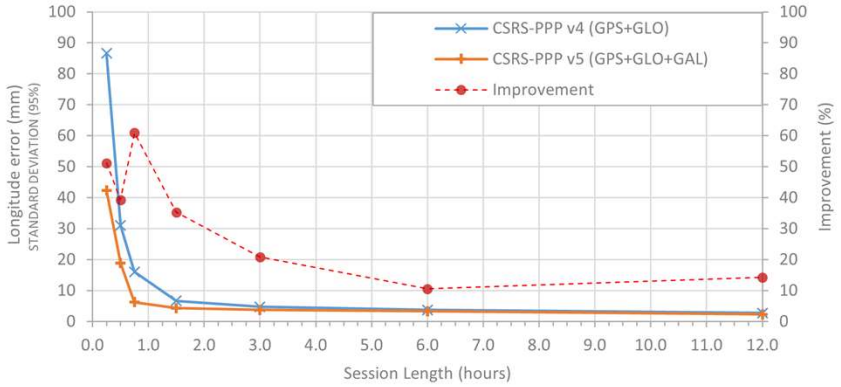
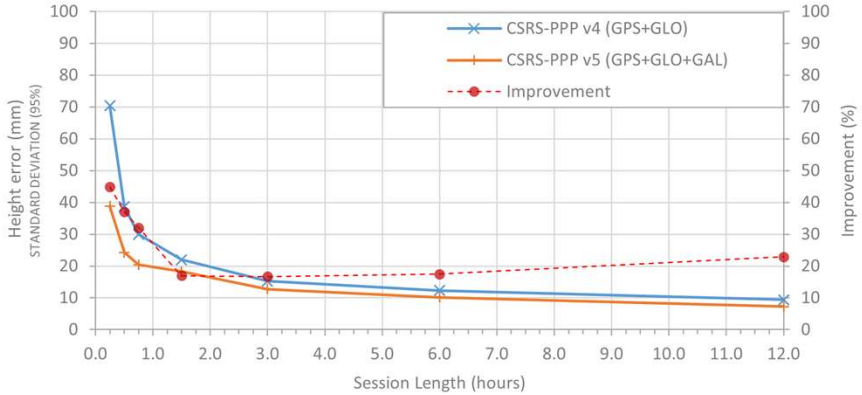
Results – improved convergence







CSRS-PPP v5 improvement with Final products for datasets between 15 minutes and 12 hours

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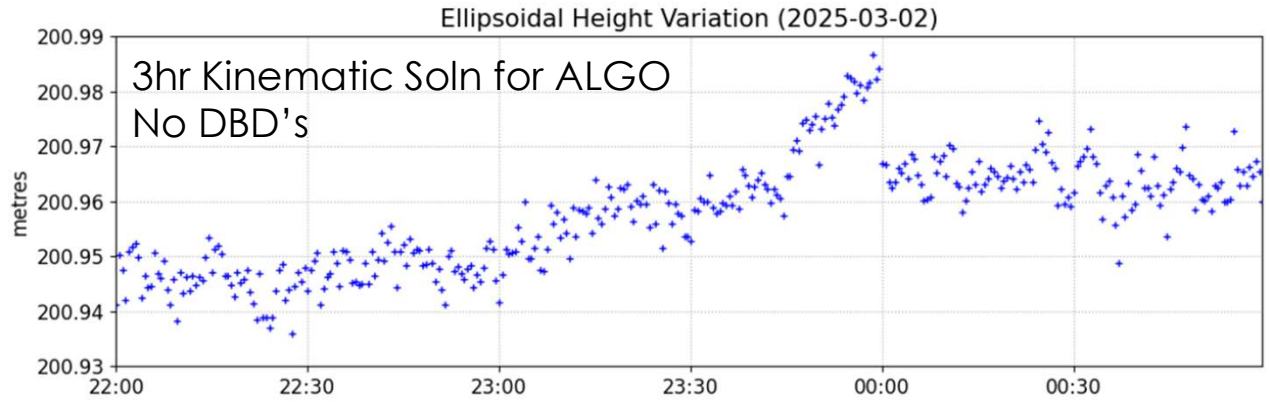
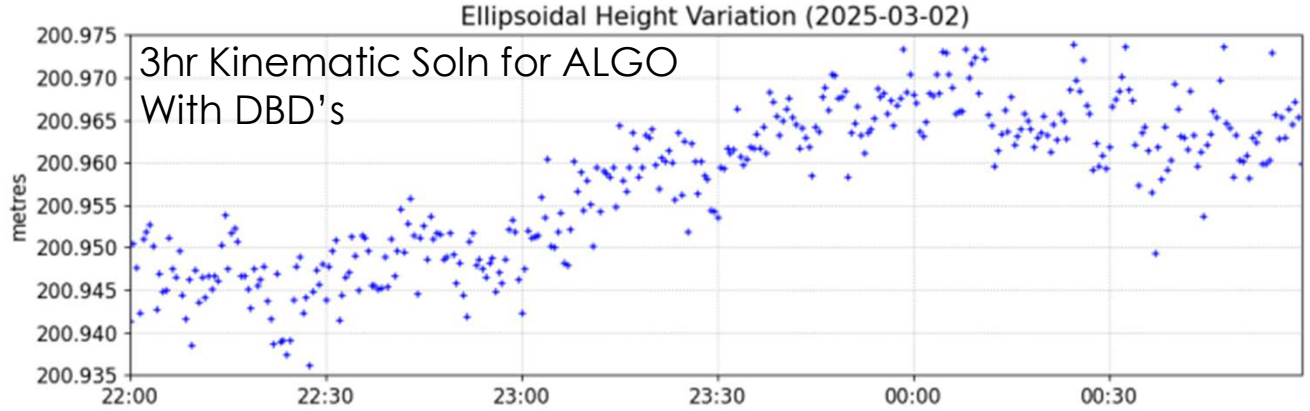
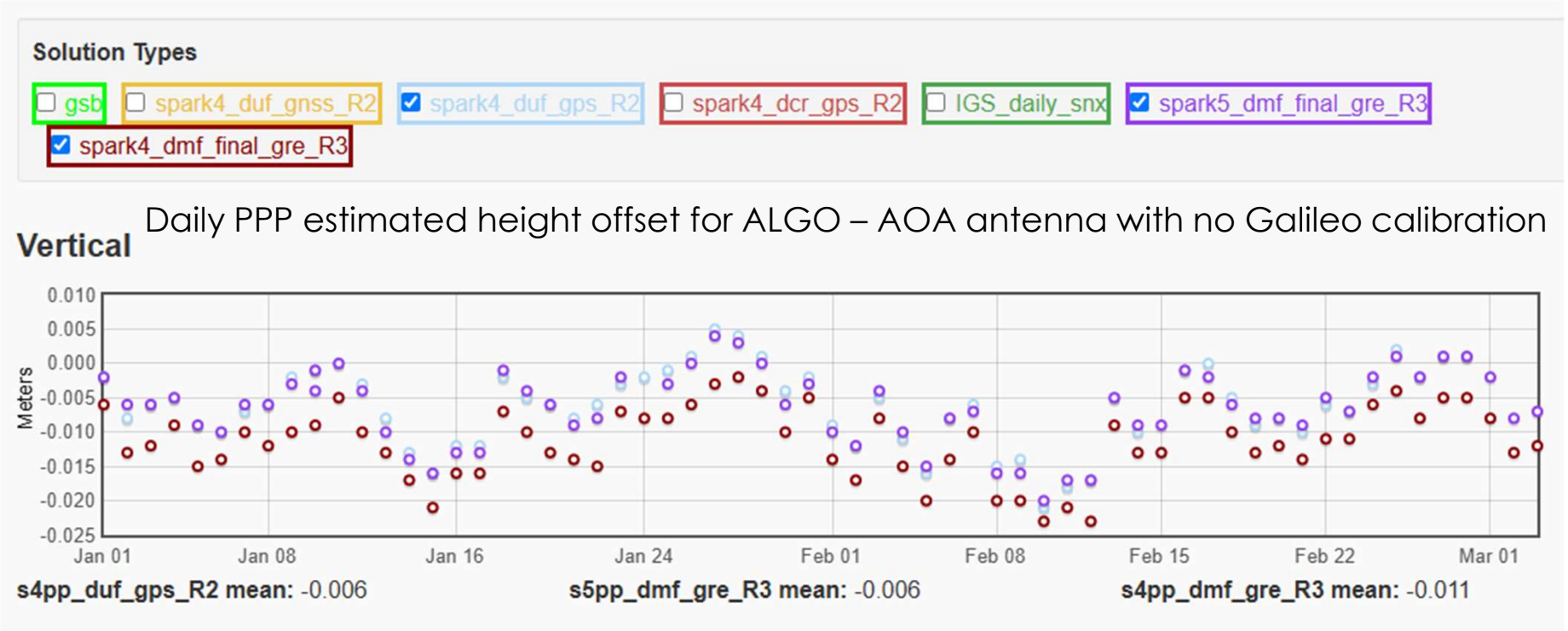
Results – Impact of applying DBD's in CSRS-PPP





Results – Impact of estimating Galileo PCO/PCV for an uncalibrated antenna (ALGO)



Future updates

- Introduce IGS repro3 products from 1994 to 2022
  - Need to estimate GPS and Galileo satellite clocks and phase biases to support PPP-AR for 2021-01-01 to 2022-11-27

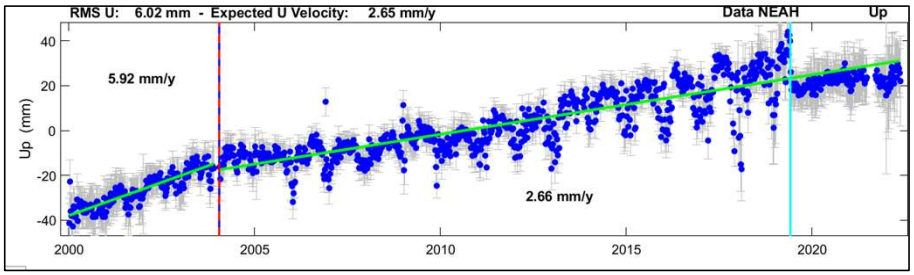
Start Date	ITRF Realization	Products Used	Orbits/Clocks	Phase Biases
1994-Mar-06	ITRF2014/IGSR3	IGS Repro3 GPS	GPS	None
2000-Jan-01	ITRF2014/IGSR3	IGS Repro3 GPS with BIA (PPP-AR)	GPS	GPS
2002-Jan-01	ITRF2014/IGSR3	IGS Repro3 GPS+GLO	GPS+GLO	GPS
2013-Jan-01	ITRF2014/IGSR3	IGS Repro3 GPS+GLO+GAL	GPS+GLO+GAL	GPS+GAL
2021-Jan-01	ITRF2014/IGSR3	IGS Repro3 extended GPS+GLO+GAL	GPS+GLO+GAL	None

- Replace CODE GLONASS and Galileo products for Rapids and Finals with NRCan products (GipsyX orbits with SPARKnet satellite clocks and phase biases)
- Add NRCan Ultra-rapid GPS/GLONASS/Galileo products

NATRF2022 Coordinates and Velocities have been Estimated

- CGS has completed reprocessing of all public ACS data
  - Used latest software & international standards
  - Generated weekly coordinate solutions
- Multi-year combinations completed
  - Discontinuities in coordinate time series modelled
  - Computed coordinates & velocities of public ACSs/RTK
  - Combination done at ITRF2020 Epoch 2020.0, transformed to NAD83(CSRS)v8.0
  - Preliminary solution for NATRF2022

Velocity Discontinuity



Position Discontinuity

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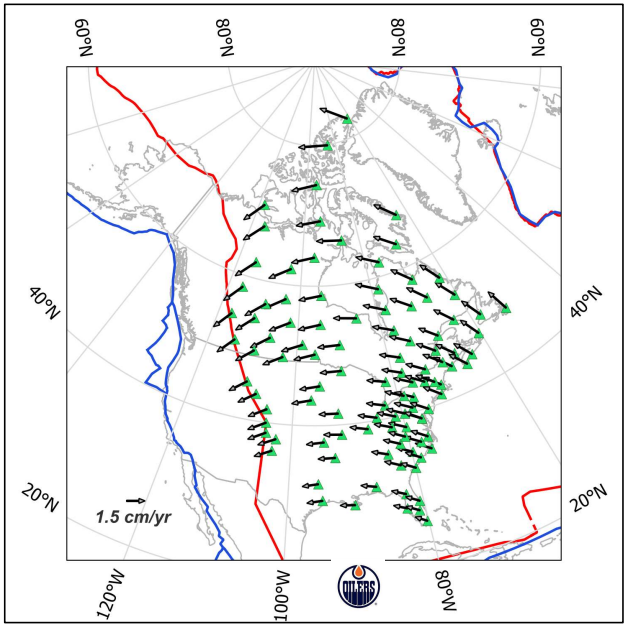
Euler Pole Parameters were estimated defining the Transformation from ITRF2020 to NATRF2022

- Collaboration between NGS and CGS has allowed EPPs to be estimated
  - A list of core stations were agreed upon to model North American plate motion
    - Located in stable part of NA
    - Stable monuments
    - 2+ years of data
  - CGS/NGS responsible for modelling its stations' discontinuities
  - Each agency independently estimated values to validate results
  - Beta values available



Desired rotations

$$\mathbf{v}_i^p = \boldsymbol{\Omega}^p \times \mathbf{x}_i = \begin{bmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{bmatrix}^p \begin{bmatrix} x \\ y \\ z \end{bmatrix}_i$$

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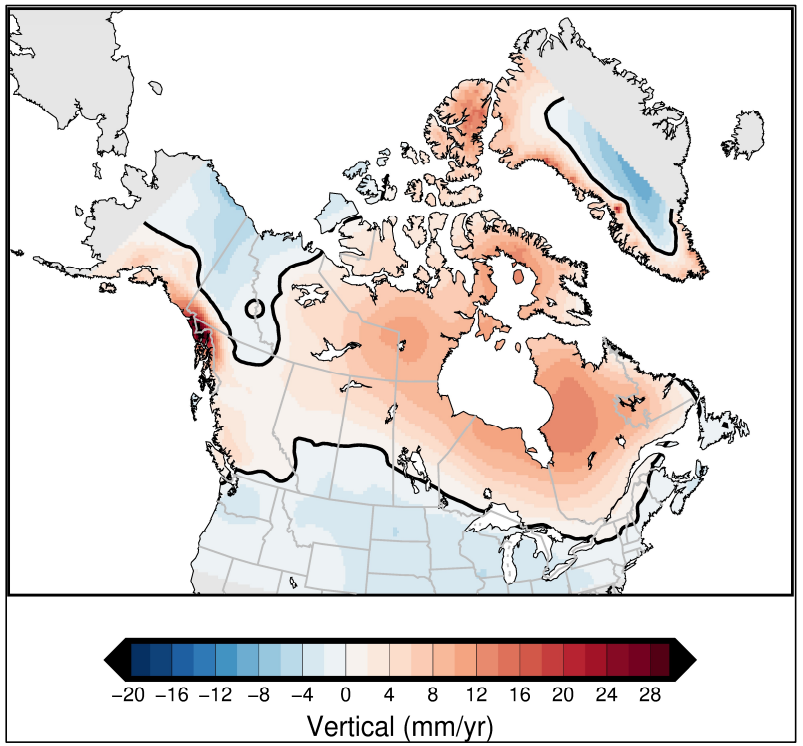
An Intraframe Deformation Model (IFDM) is used to capture residual motion not captured by the EPPs

- IFDM is currently a velocity grid in Canada
- It may evolve to include more sophisticated modelling (coordinate functions and GGXF to be discussed at a later time)
- Next presentation will look at the velocity model in more detail



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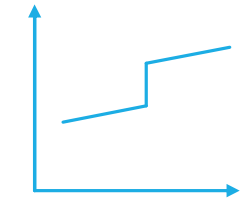
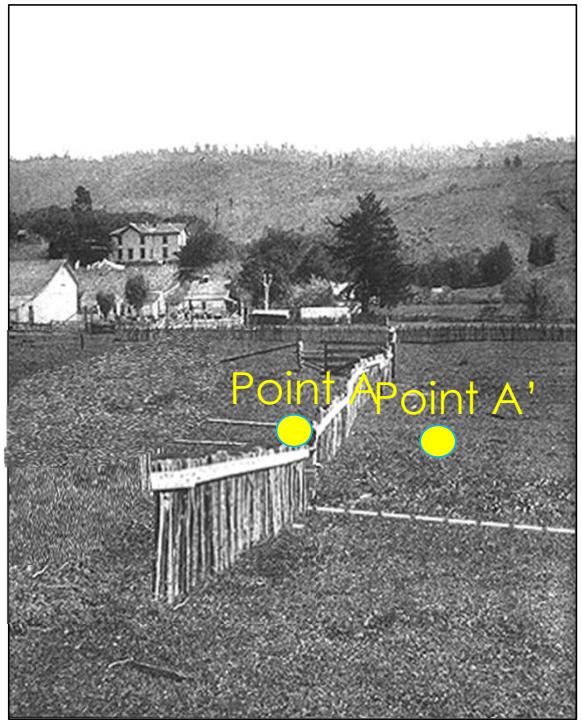
Coordinate Function Retracing of Position

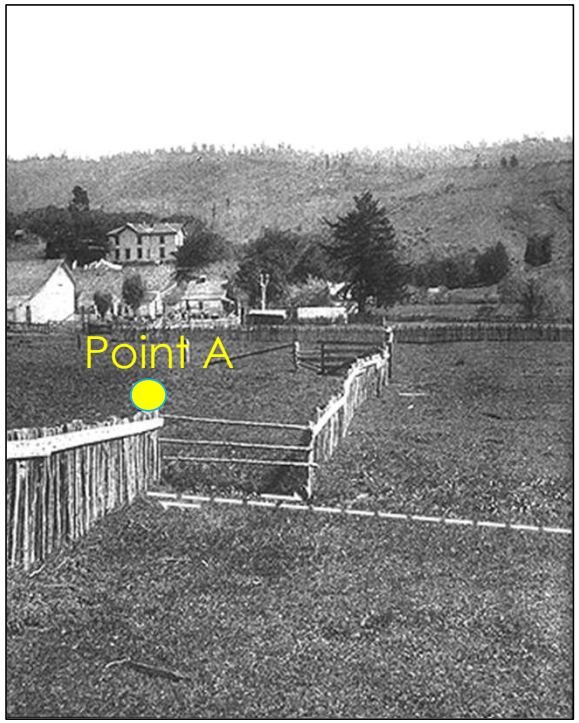
Point A Northing



2010.0 2010.5 2010.0



Previous State

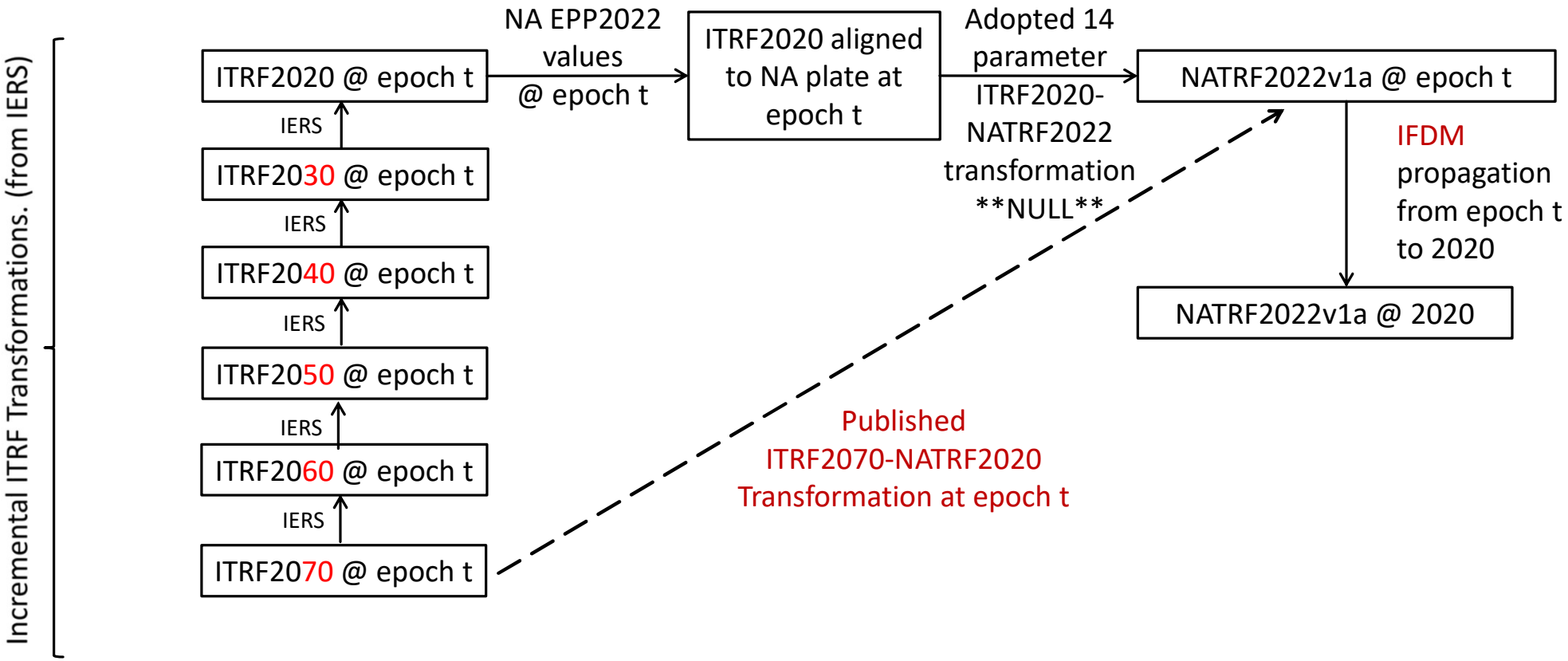


Current State

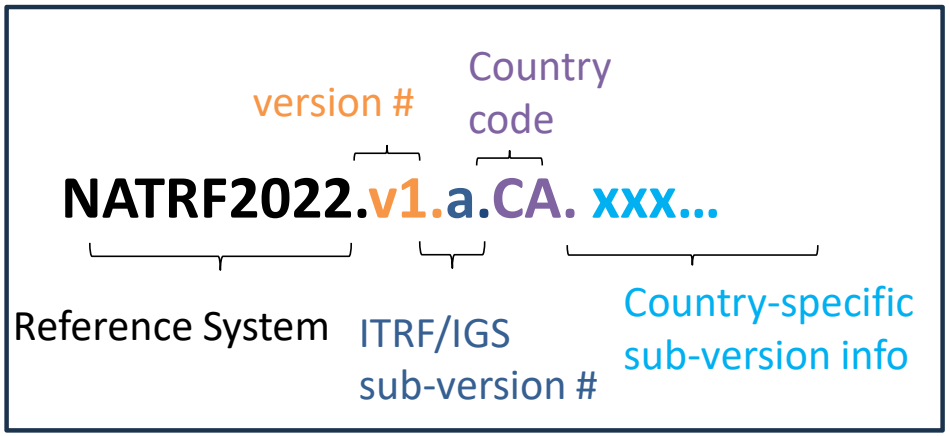
Using the current velocity alone, the current state would show the same fence location in previous state (Point A')

A coordinate function could be used to apply the Earthquake offset and recreate the actual previous fence location. Knowledge of the fault zone would be needed.

Example Progression of NATRF Updates

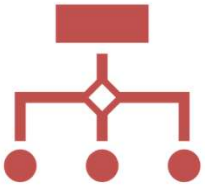


Geometric Reference Frame Version Naming



- Reference System name:
  - Official reference system name
  - Changes when the system definition changes . E.g., Euler pole parameters change, origin change…
  - Fixed number of characters?
- Reference frame version
  - V1 upon rollout. ITRF2020
  - V2 ITRF20XX
- Reference frame subversion – e.g., a,b,c…
  - ‘a’ upon rollout
  - Follows annual changes to ITRF/IGS (which are to be aligned going forward).
  - ITRF2020-u2303
- Country code: Canada (CA), United States (US)
- Country specific sub version information: solution number, deformation model, projection information, geoid information...etc. Changes when geodetic network is expanded, minor coordinate revisions are made.

Next Steps



Medium Term:

Combination to the end of 2024 that will serve as the foundation for NATRF2020 and NAD83(CSRS)v8.1

Publication of North America EPPs

Long Term:

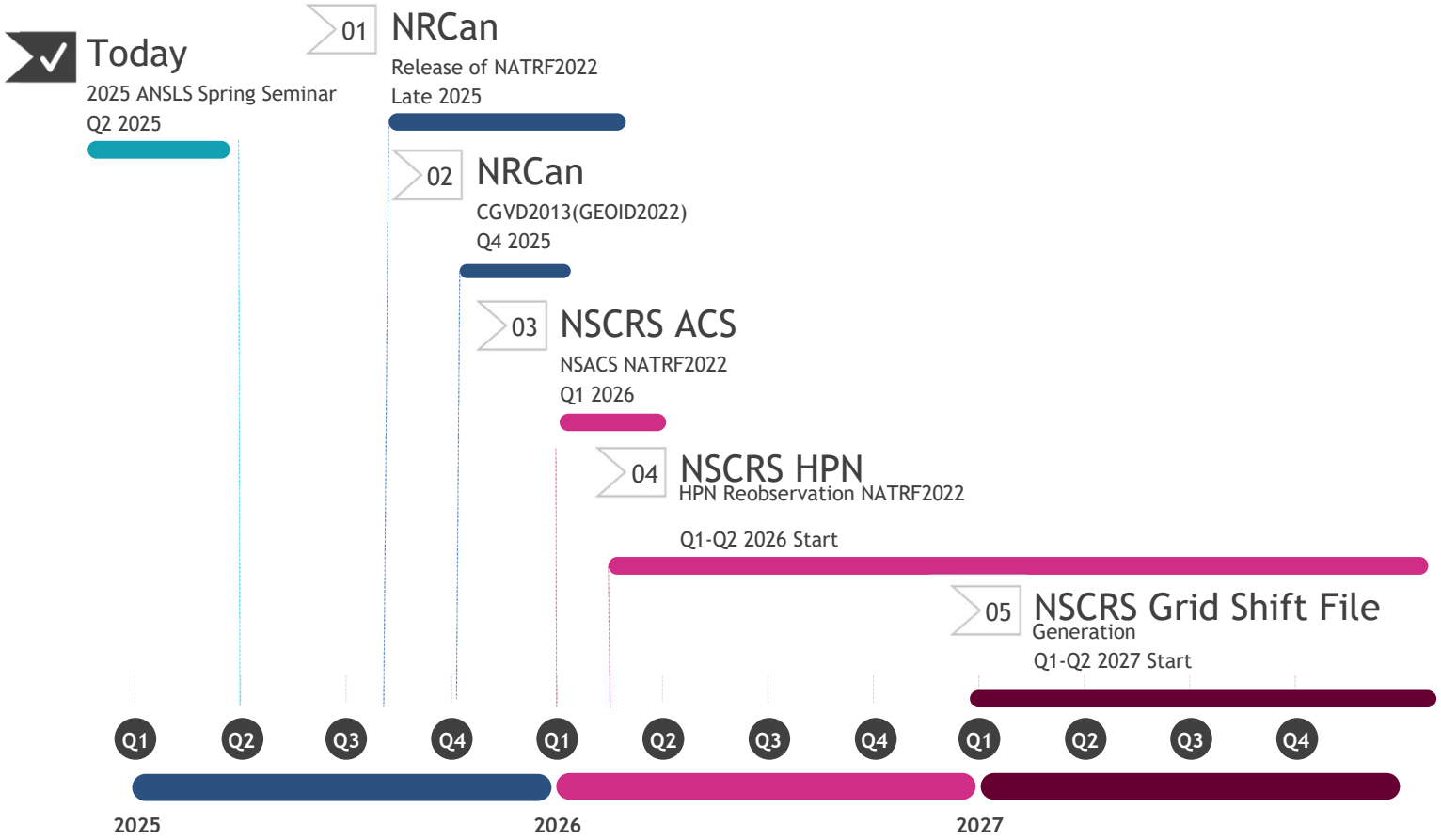
Development of Coordinate Functions

Development of more complex IFDM

NATRF 2022 – Nova Scotia Implementation

- Upgrades of NSACS receivers and antennas– 2025 – 2029
- NRTK Correction software – GEO++ (~mid of 2025 fiscal year)
- NATRF2022 NSACS coordinates – as provided by NRCAN ~2025
- NATRF2022 access – as soon as NSACS coordinates are updated
  - Staged roll out to full implementation
- HPN NATRF2022 – as soon as NSACS coordinates are updated
- Tools for Coordinate Transformation – NRCan

Nova Scotia NATRF2022 and CGVD2013(NAPGD22) Implementation Plan



GeoNOVA

Thank you

NOVA SCOTIA