Reference System Modernization: Canadian plans and timelines

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Presentation outline

- Part 1 - Reference System Modernization
  - US & Canadian plans
  - Rationale
- Part 2 - Working in a modernized Canadian Spatial Reference System (CSRS)
  - Impact of modernization
  - Products & tools
  - Phased roll-out
- Part 3 - Unifying reference frames in Canada
  - National goals & roadmap
  - Modernization options (georeferencing & geospatial)

Part 1 – CSRS modernization

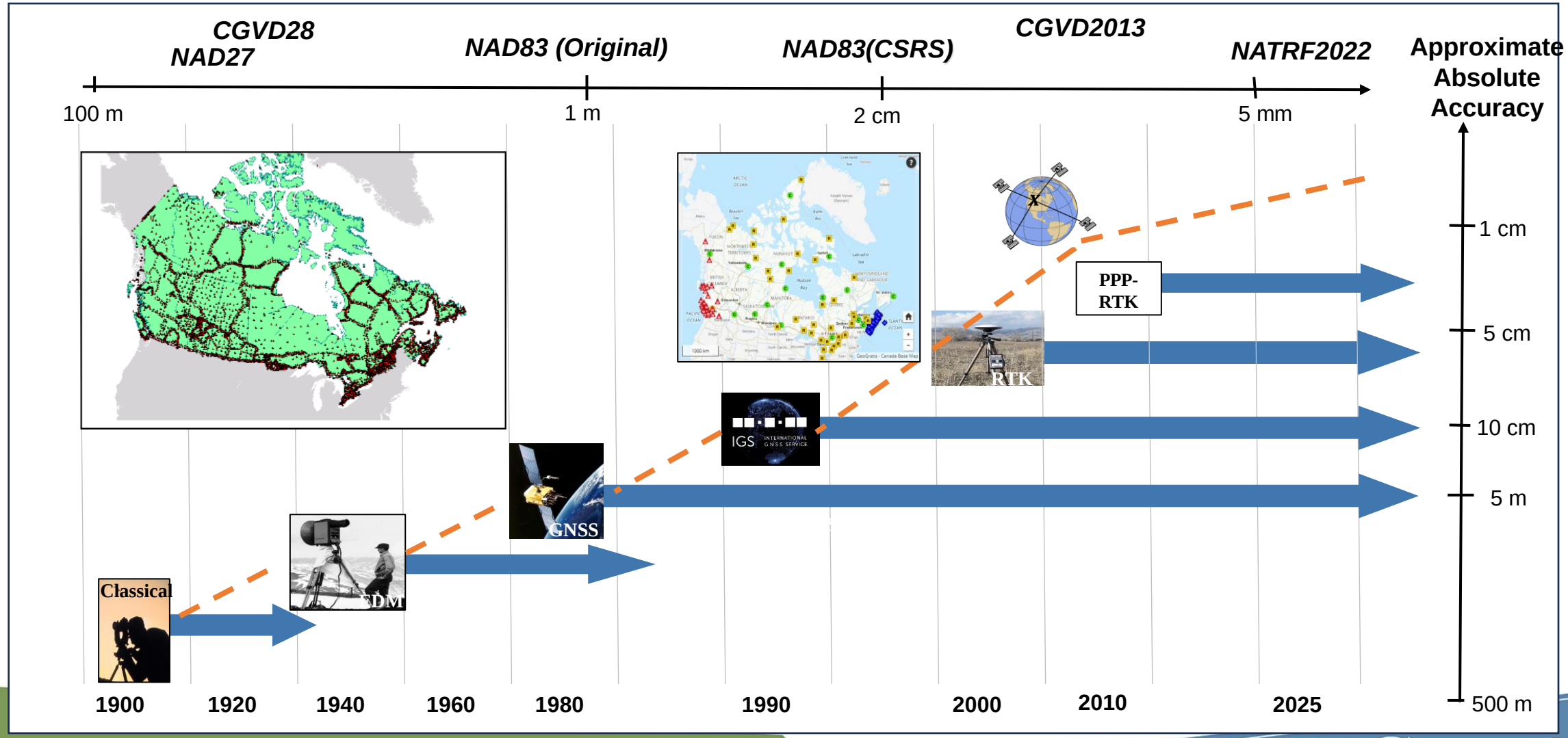
- US & Canadian plans
- Rationale

Canada and the US will modernize their Spatial Reference Systems in 2025

- For the geometric system:
  - Both countries will replace the North American Datum of 1983 (**NAD83**) with the North American Terrestrial Reference Frame of 2022 (**NATRF2022**)
- For the height system:
  - The US (and Mexico) will replace the North American Vertical Datum of 1988 (**NAVD 88,** a leveling-based height system) with the North American Pacific Geopotential Datum of 2022 (**NAPGD2022,** a geoid-based height system)
  - Canada will update the realization of the Canadian Geodetic Vertical Datum of 2013 (**CGVD2013,** a geoid-based height system) with a new North American geoid model, which will also be adopted by the US (and Mexico) as their realization of NAPGD2022

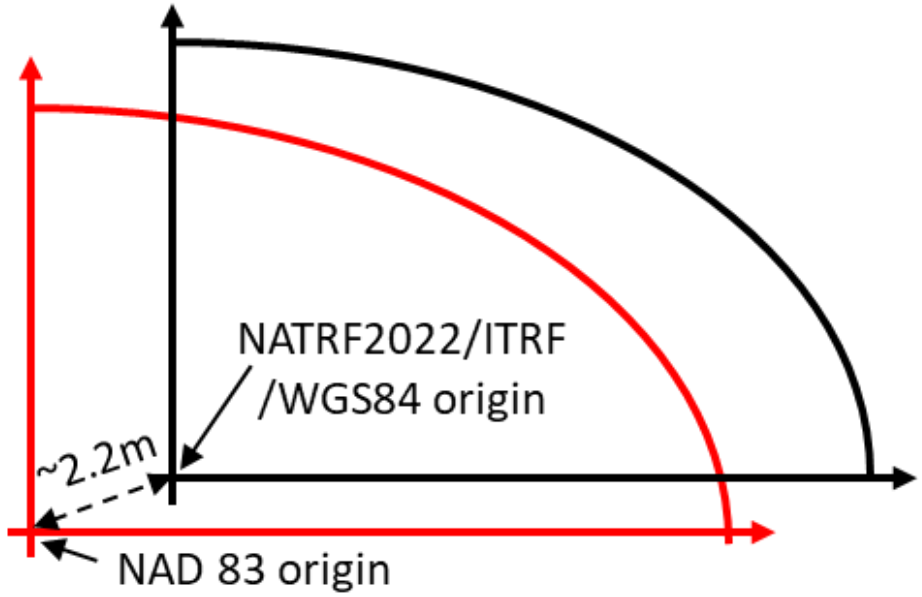
History of modernizations in Canada

Reference frame accuracies stay ahead of the technology



Rationale for modernization in 2025

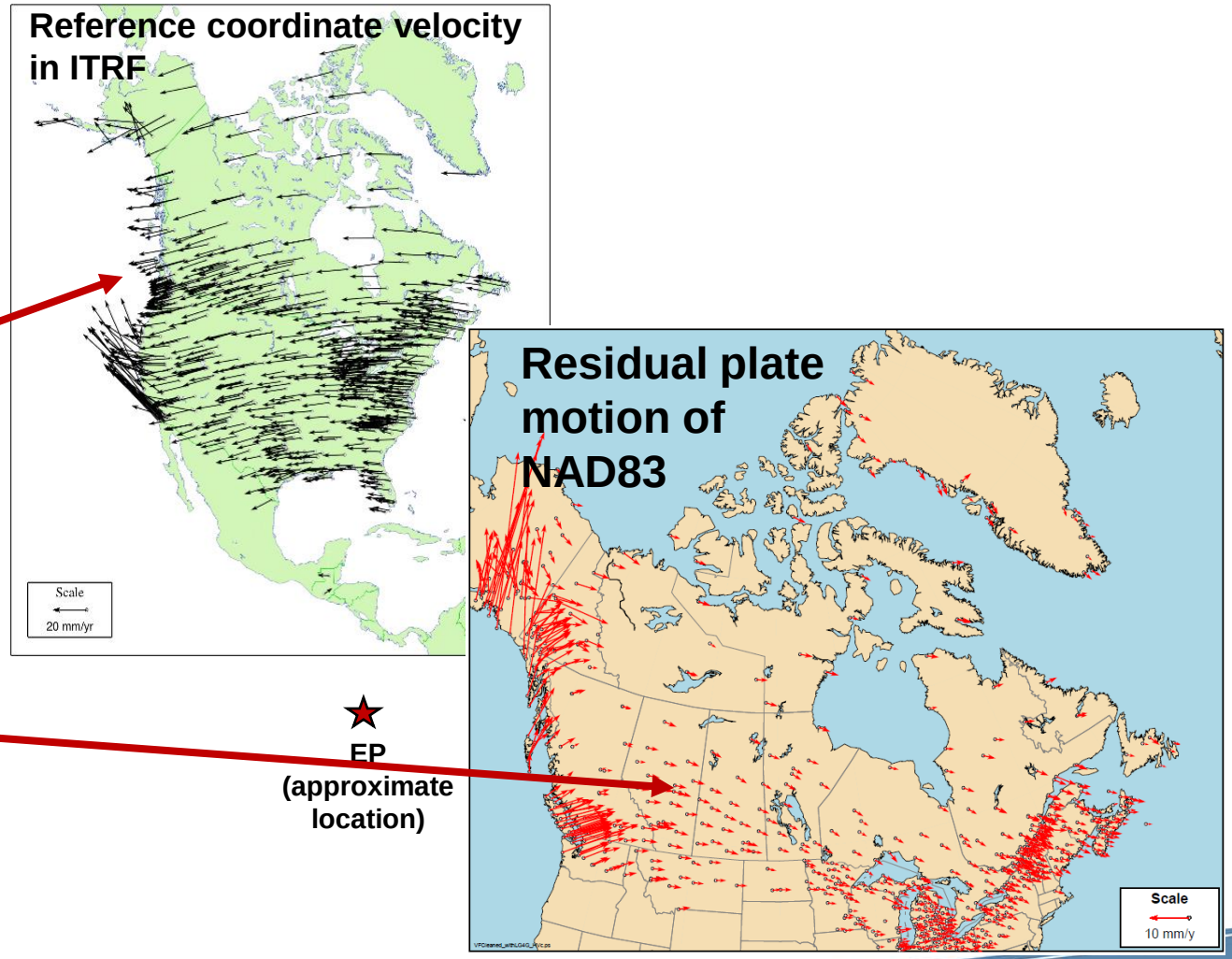
- NAD83 is not a geocentric reference system as the origin is off by about 2.2m
- GNSS systems (e.g., GPS) and the ITRF are geocentric
- NATRF2022 will better support precise positioning from space (GNSS)



Rationale for Modernization in 2025

The Earth is dynamic and the Canadian Spatial Reference System (CSRS) accounts for:

1. Tectonic plate motion
   - The North American plate rotates relative to the global reference system
   - The rotation is described by Euler Pole Parameters (EPPs)
   - The EPPs defining NAD83 have a significant residual



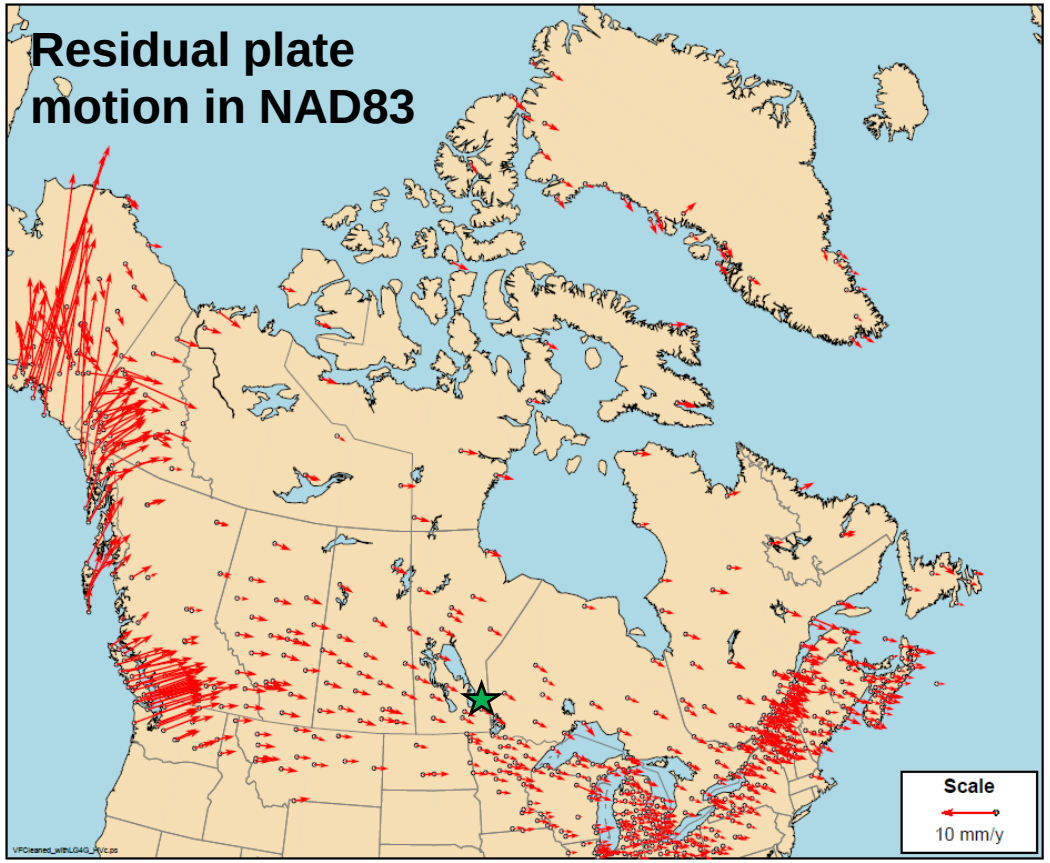
Rationale for Modernization in 2025

- NATRF2022 will also be kept fixed to the North American plate with new and improved EPP's

For e.g., at DUBO CACS station (Lac Dubonnet):★

Ref. Frame	Hor. Velocity	Hor. displacement since 2010
ITRF2020	18.1mm/yr	25.1cm
NAD83(CSRS)	2.5mm/yr	3.5cm
NATRF2022*	0.7mm/yr	1.0cm

*Preliminary value

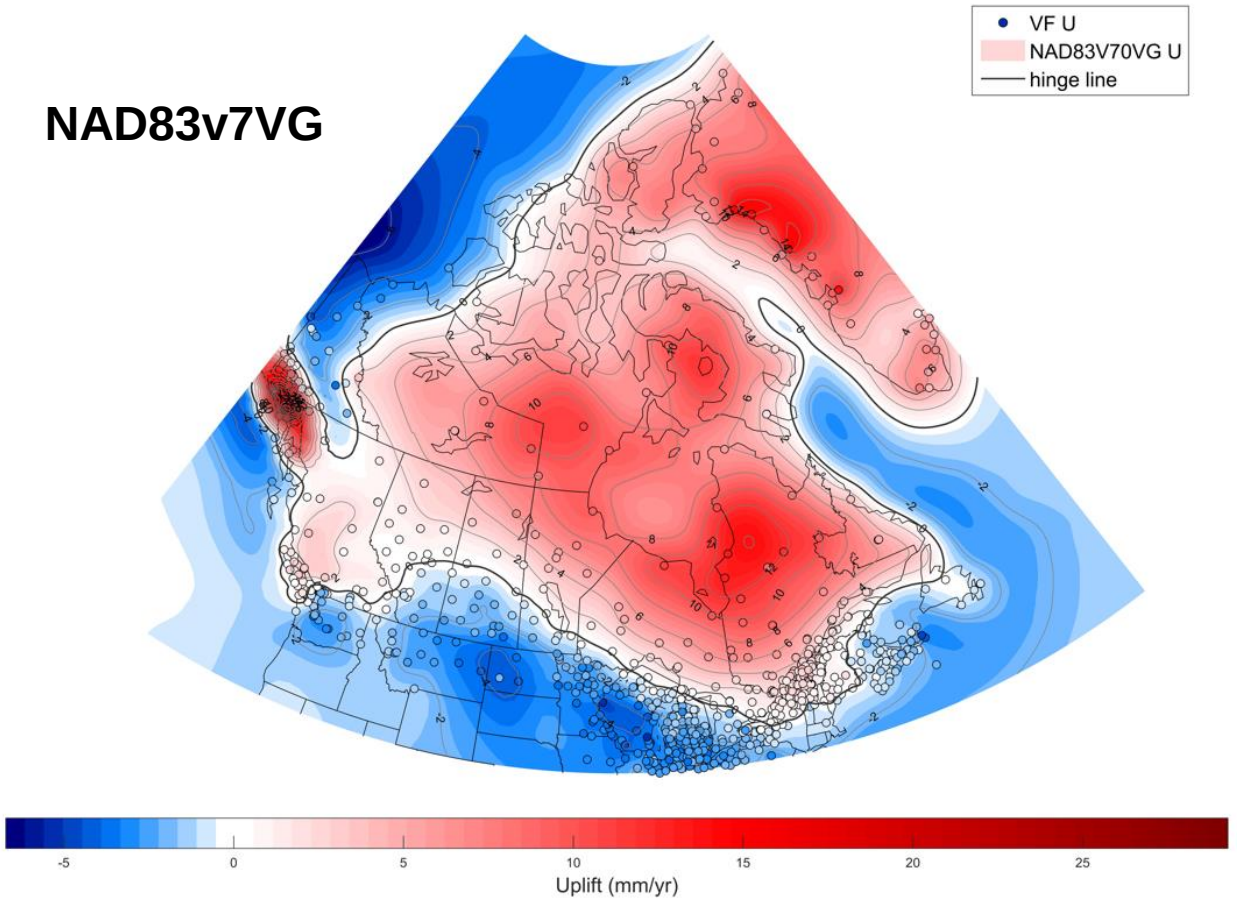


Rationale for Modernization in 2025

The Earth is dynamic and the CSRS accounts for:

2. Intraplate motions
   - Predictable (e.g., glacial isostatic adjustment)
   - Unpredictable (e.g., earthquakes)

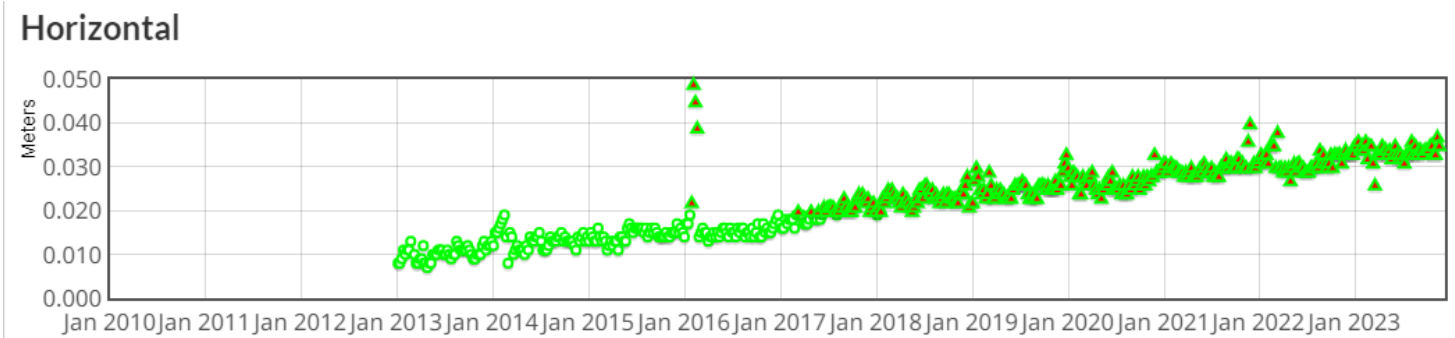
- New standards and tools to capture more complex models
- Model inputs will be coordinated with the US



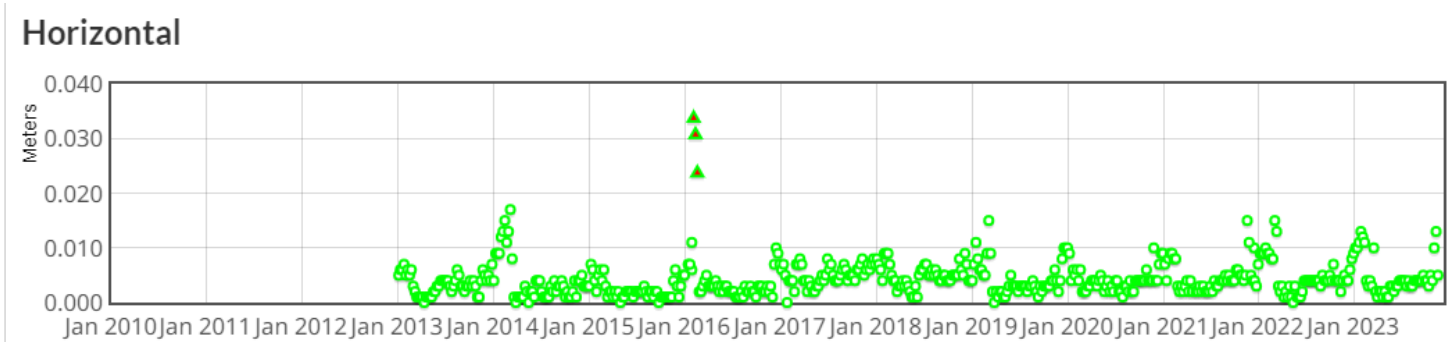
Rationale for Modernization in 2025

NATRF2022 will include:

- **Coordinate functions;** and
- An **intra-frame deformation model (IFDM)**
  - In NAD83(CSRS) this was the velocity model
  - Will account for residual plate and regional motions
  - Derived from compatible CGS/NGS coordinate functions and geophysical models
  - Will support propagating coordinates to different epochs



DUBO horizontal time-series in NAD83(CSRS)

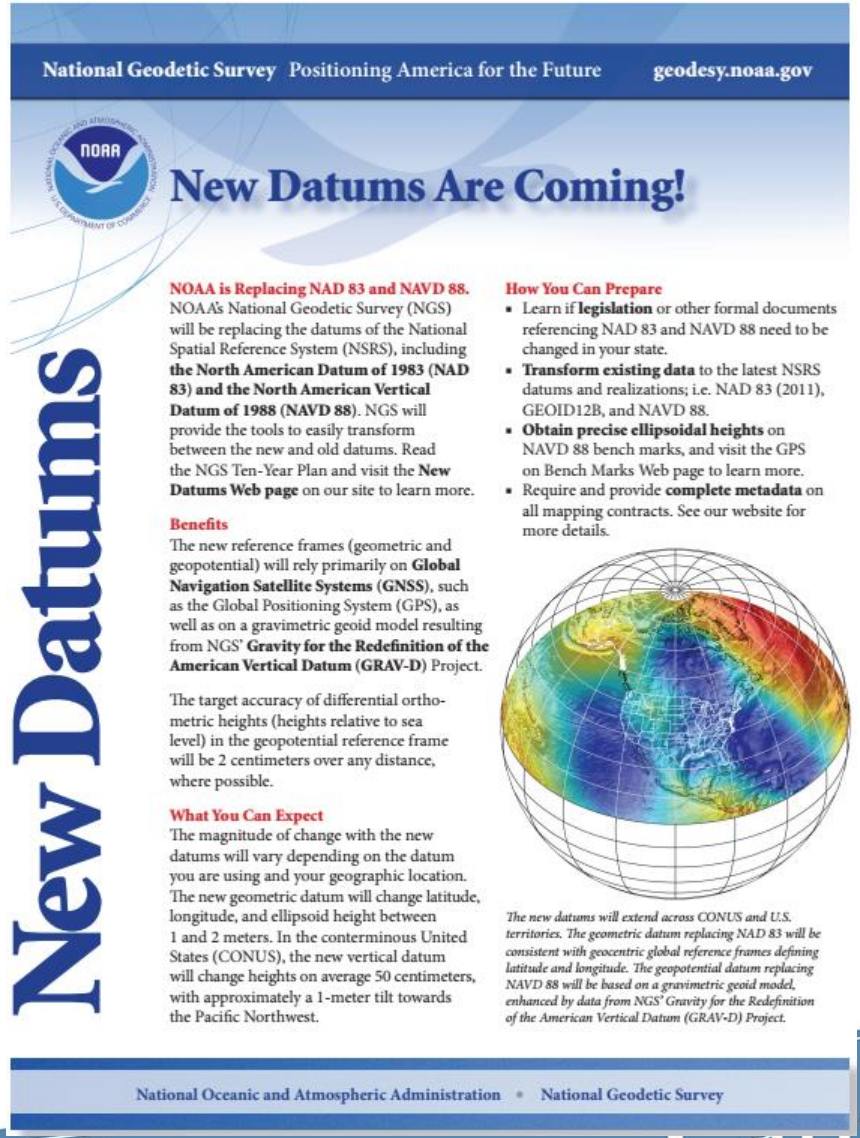


DUBO horizontal time-series in NAD83(CSRS) with velocity model (IFDM) applied

Rationale for modernization in 2025

In summary, the rationale for both countries includes:

- NATRF2022 will be better aligned with international standards (e.g., ITRF and WGS 84)
- It will be geocentric and better support mass-market GNSS applications (existing & emerging)
- It will be more accurately fixed to the North American plate
- It will have a more consistent IFDM across the Canada / US border



National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

New Datums Are Coming!

New Datums

NOAA is Replacing NAD 83 and NAVD 88.
NOAA's National Geodetic Survey (NGS) will be replacing the datums of the National Spatial Reference System (NSRS), including **the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88)**. NGS will provide the tools to easily transform between the new and old datums. Read the NGS Ten-Year Plan and visit the **New Datums Web page** on our site to learn more.

Benefits
The new reference frames (geometric and geopotential) will rely primarily on **Global Navigation Satellite Systems (GNSS)**, such as the Global Positioning System (GPS), as well as on a gravimetric geoid model resulting from NGS' **Gravity for the Redefinition of the American Vertical Datum (GRAV-D)** Project.

The target accuracy of differential ortho-metric heights (heights relative to sea level) in the geopotential reference frame will be 2 centimeters over any distance, where possible.

What You Can Expect
The magnitude of change with the new datums will vary depending on the datum you are using and your geographic location. The new geometric datum will change latitude, longitude, and ellipsoid height between 1 and 2 meters. In the conterminous United States (CONUS), the new vertical datum will change heights on average 50 centimeters, with approximately a 1-meter tilt towards the Pacific Northwest.

How You Can Prepare
- Learn if **legislation** or other formal documents referencing NAD 83 and NAVD 88 need to be changed in your state.
- **Transform existing data** to the latest NSRS datums and realizations; i.e. NAD 83 (2011), GEOID12B, and NAVD 88.
- **Obtain precise ellipsoidal heights** on NAVD 88 bench marks, and visit the GPS on Bench Marks Web page to learn more.
- Require and provide **complete metadata** on all mapping contracts. See our website for more details.

The new datums will extend across CONUS and U.S. territories. The geometric datum replacing NAD 83 will be consistent with geocentric global reference frames defining latitude and longitude. The geopotential datum replacing NAVD 88 will be based on a gravimetric geoid model, enhanced by data from NGS' Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project.

National Oceanic and Atmospheric Administration • National Geodetic Survey

NATRF2022 better supports emerging applications

U.S. NGS Whitepaper (2010) - *Improving the National Spatial Reference System*:

"A two-meter non-geocentricity, which will manifest itself as latitude, longitude and ellipsoid height errors of ± 2 meters (globally), in a world where sub-meter instantaneous positioning will be in most handheld devices, will be a glaring error to general users."

"It is impractical to assume that the appropriate datum transformation would be coded accurately in every personal handheld positioning device to correct for this [offset]…Even today there persists software which treats WGS 84 as equivalent to NAD 83. Rather than risk life and property to such misunderstandings, NGS feels that a geocentric datum is the best approach."

What about NAPGD2022 / CGVD2013?

- NAGPD2022 is a geoid-based datum
  - The geoid is tied to the ellipsoid and therefore is more compatible with GNSS
- The Canadian Geodetic Vertical Datum of 2013 is already a geoid-based datum: CGVD2013(CGG2013a)
- NAPGD2022 will use the same equipotential surface defining mean sea level ($W_0 = 62{,}636{,}856.0\ m^2s^{-2}$), which was agreed upon by Canada and the US in 2012

Rationale for CSRS modernization

- Improved reference frames
- Supports compatibility along the Canada / U.S. border, with international standards, and with commercial products supporting the US market
- CSRS modernization also provides an opportunity to unify reference system adoption across Canada

NRC Research Press

TECHNICAL NOTE

The U.S. is replacing NAD83 with NATRF2022: what this means for Canada

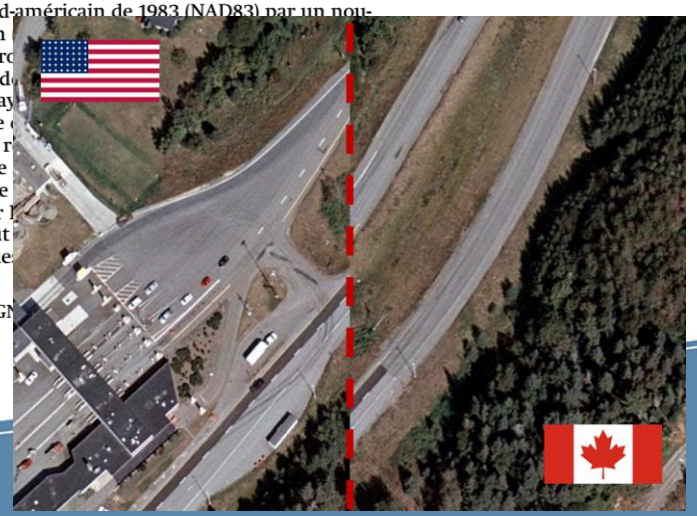
Caroline Erickson, Geoff Banham, Ron Berg, Joey Chessie, Michael Craymer, Brian Donahue, Renée Tardif, Yves Thériault, and Marc Véronneau

Abstract: In 2022, the U.S., as part of its reference system modernization, will replace its North American Datum of 1983 (NAD83) with a new North American Terrestrial Reference Frame (NATRF2022), creating 1.3 to 1.5 m horizontal coordinate differences at the Canada–U.S. border with respect to Canada's NAD83(CSRS). Never before have such significant differences existed between our two countries' reference frames. This paper reviews why the U.S. is making this change and then looks at Canada's situation with respect to reference frames. There are compelling reasons for Canada to follow suit and move to NATRF2022 within a decade, but there are also major challenges. Whether or not Canada follows the same path, there is much work to be done to prepare Canada for the U.S.' move to NATRF2022. This paper is intended as a first step to inform the Canadian geospatial community of the U.S.' move to NATRF2022 and what it means for Canada.

Key words: NATRF, NAD83, reference frame, CSRS, GNSS.

Résumé : En 2022, dans le cadre de la modernisation de leur système de référence, les États-Unis remplaceront leur Système de référence nord-américain de 1983 (NAD83) par un nouveau Cadre de référence terrestre nord-américain (NATRF2022), créant des différences de coordonnées horizontales de 1.3 à 1.5 mètre à la frontière entre le Canada et les États-Unis par rapport au NAD83(SCRS) du Canada. Jamais auparavant de telles différences importantes n'avaient existé entre les cadres de référence de nos deux pays. Le présent article examine donc la raison pour laquelle les États-Unis effectuent ce changement et analyse ensuite la situation du Canada relativement aux cadres de référence. Il existe des raisons convaincantes pour que le Canada fasse de même et passe au NATRF2022 dans une décennie, mais il existe également des problèmes majeurs. Que le Canada suive la même voie ou non, il a beaucoup de travail à accomplir pour préparer la communauté géospatiale canadienne du passage de... signifie pour le Canada. [Traduit par la Rédaction]

Mots-clés : NATRF, NAD83, cadre de référence, SCRS, GN...

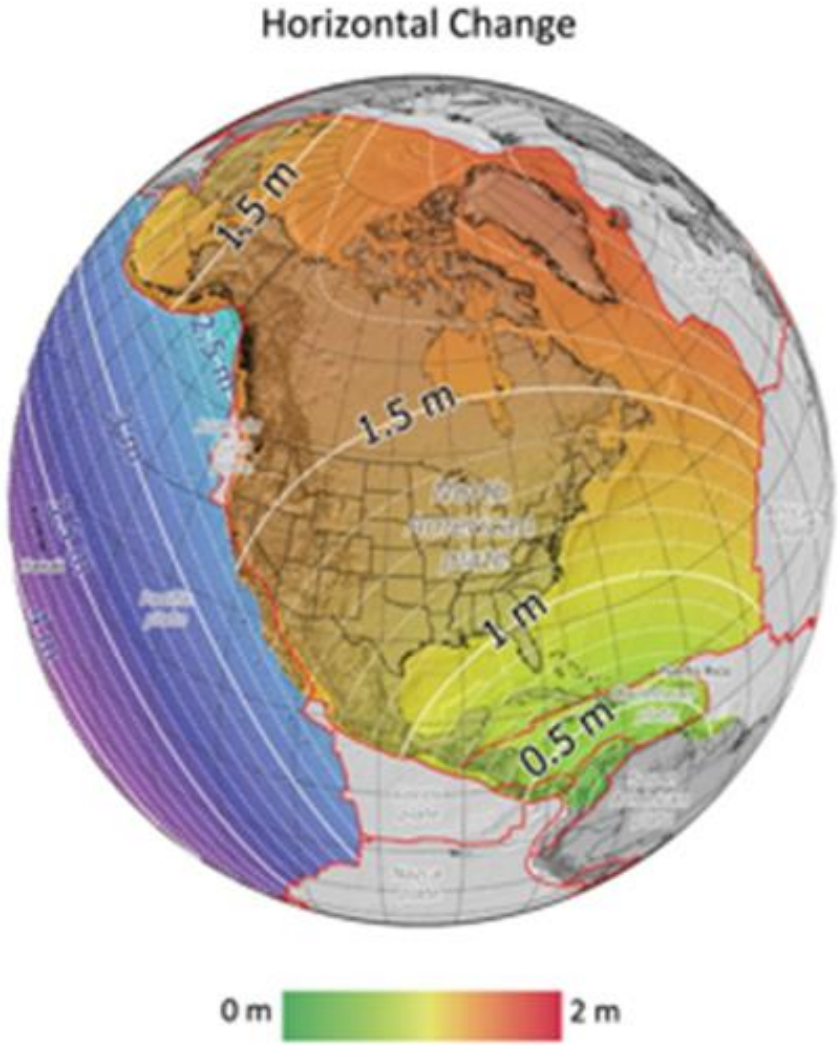


Part 2 – Working in a modernized CSRS

- Impact of Modernization
- Products & Tools
- Phased Roll-out

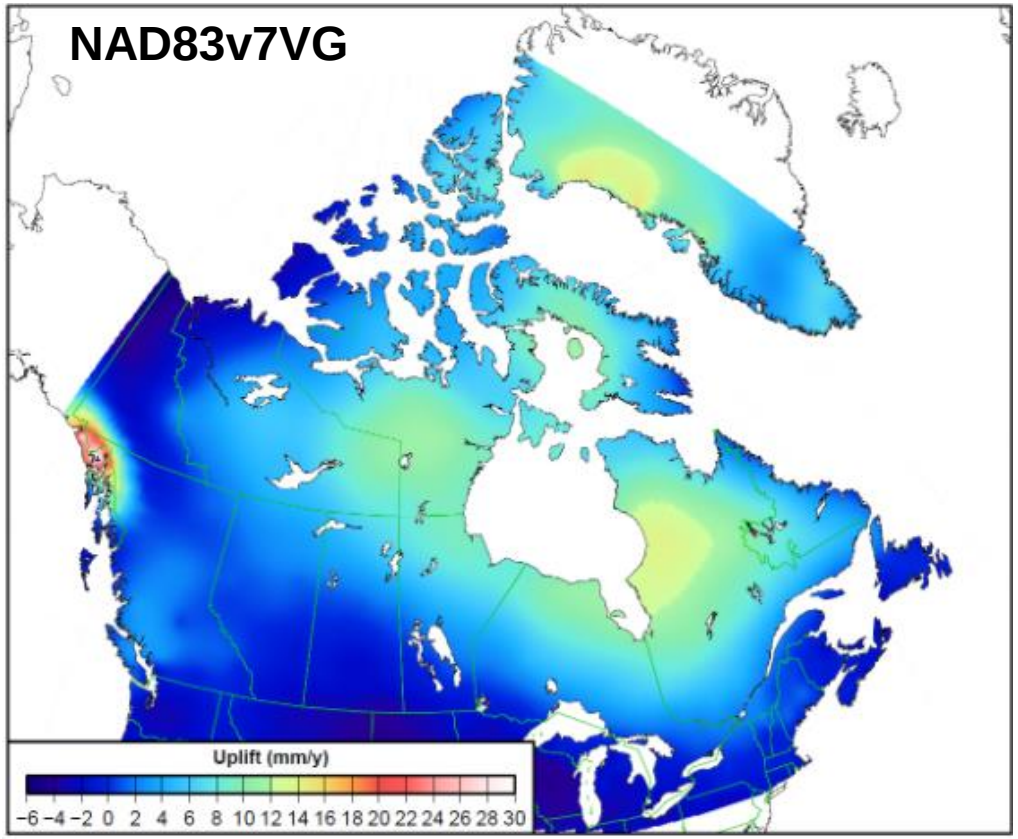
NATRF2022 vs NAD83

- Coordinates in NATRF2022 and NAD83 will have ~1-2 m 3D geometric differences across Canada
- At epoch 2020.0, NATRF2022 coordinates will be equal to ITRF2020 coordinates
- For coordinates at the same epoch, the transformation between NAD83 and NATRF2022 is mathematical
- Transformation parameters will be available for download from CGS' website and through the [ISO Geodetic Registry]



NATRF2022 vs NAD83

- NATRF2022's IFDM will initially be an improved version of the familiar crustal motion / velocity model, but will use common GNSS datasets with the US
- The IFDM will evolve in complexity after 2025, enabled by new international standards



CGVD2013 / NAPGD2022

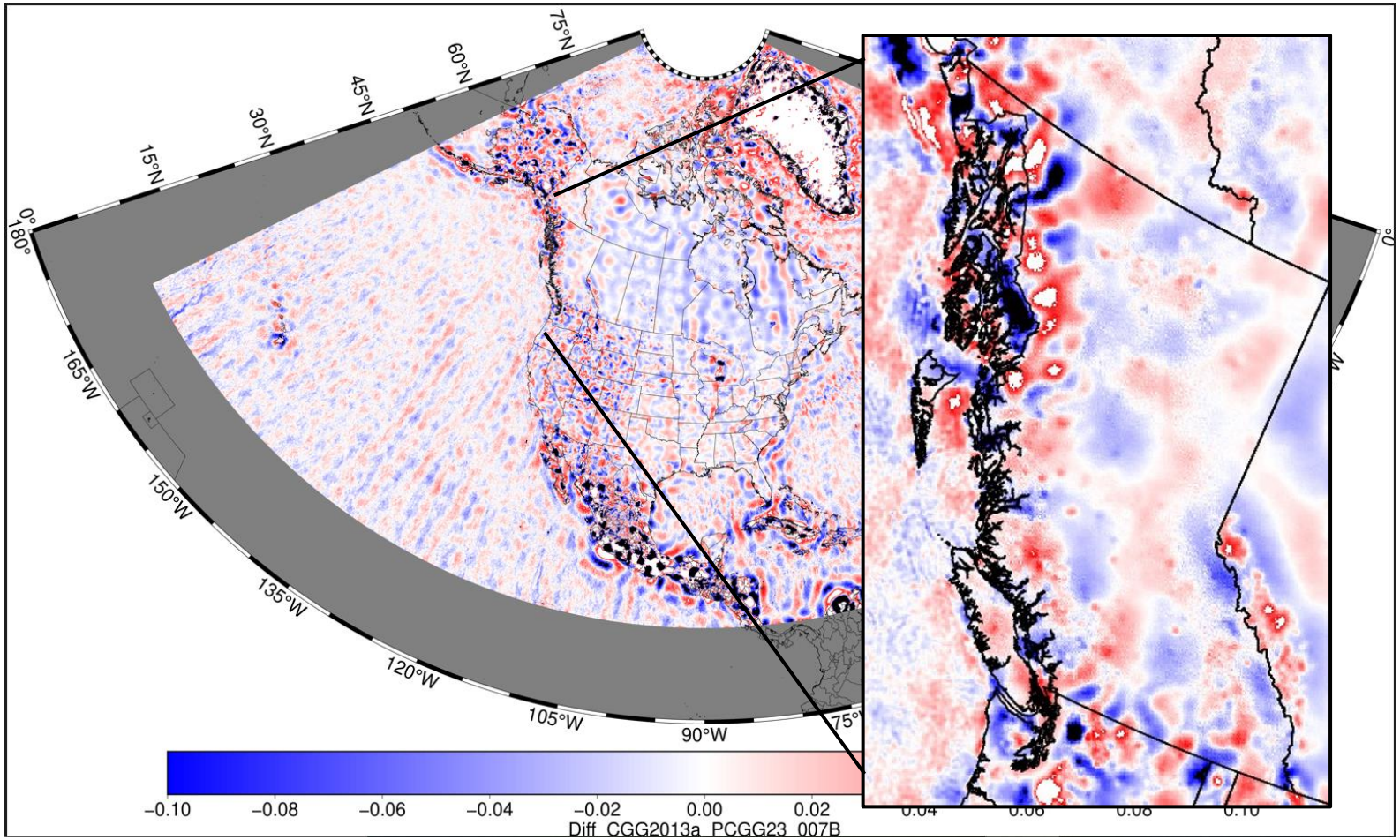
- NAPGD2022 will use the same definition of MSL as CGVD2013
- CGVD2013 will be updated using a common N.A. geoid model with the US and Mexico

CGVD2013(CGG2013a)

⇒

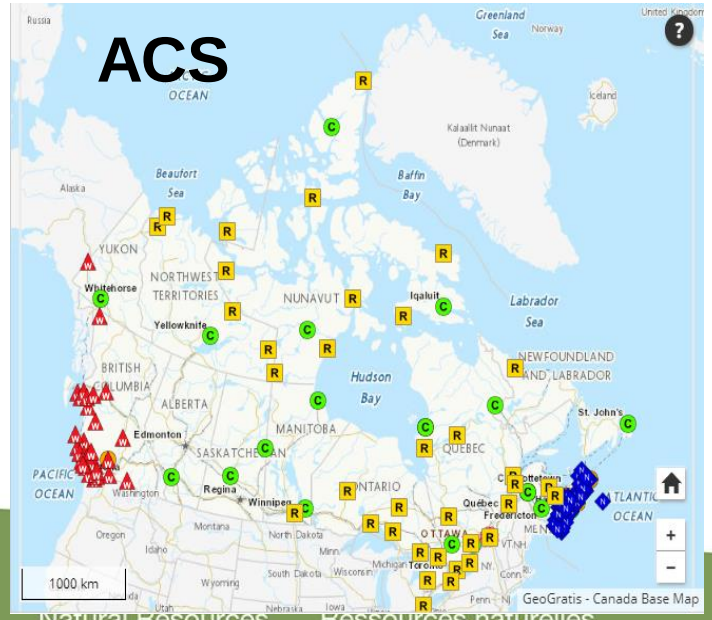
CGVD2013(GEOID2022)

- Improved with small differences in most areas
  - Removal of artifacts from satellite gravity data
  - Better elevation data in the mountains



Working in the modernized CSRS: coordinates and velocities – active control

- CGS will provide coordinates and coordinate functions for public and private ACS's in NATRF2022
- Continued support for NAD83 for some time



Changing these fields will auto-update the station coordinate information below.

Coordinates	Reference Frame	Vertical Datum	Geoid	Epoch
Geographic	NATRF2022	CGVD2013	GEOID2022	2020.0

NATRF2022 (selected)
NAD83(CSRS)
ITRF2020
ITRF2014
ITRF2008
ITRF2005
ITRF2000
ITRF97
ITRF96
ITRF94
ITRF93
ITRF92
ITRF91
ITRF90
ITRF89
ITRF88

GEOID2022 (selected)
CGG2013a
CGG2013

The velocities ar … time series at the stati…

Latitude		h (metres)
N50° 15' 31.71033"	1' 58.263188" ± 0.0002m	245.286 ± 0.0006m

Vϕ (mm/y)		Vh (mm/y)
-0.68 ± 0.04	0.02	0.49 ± 0.06

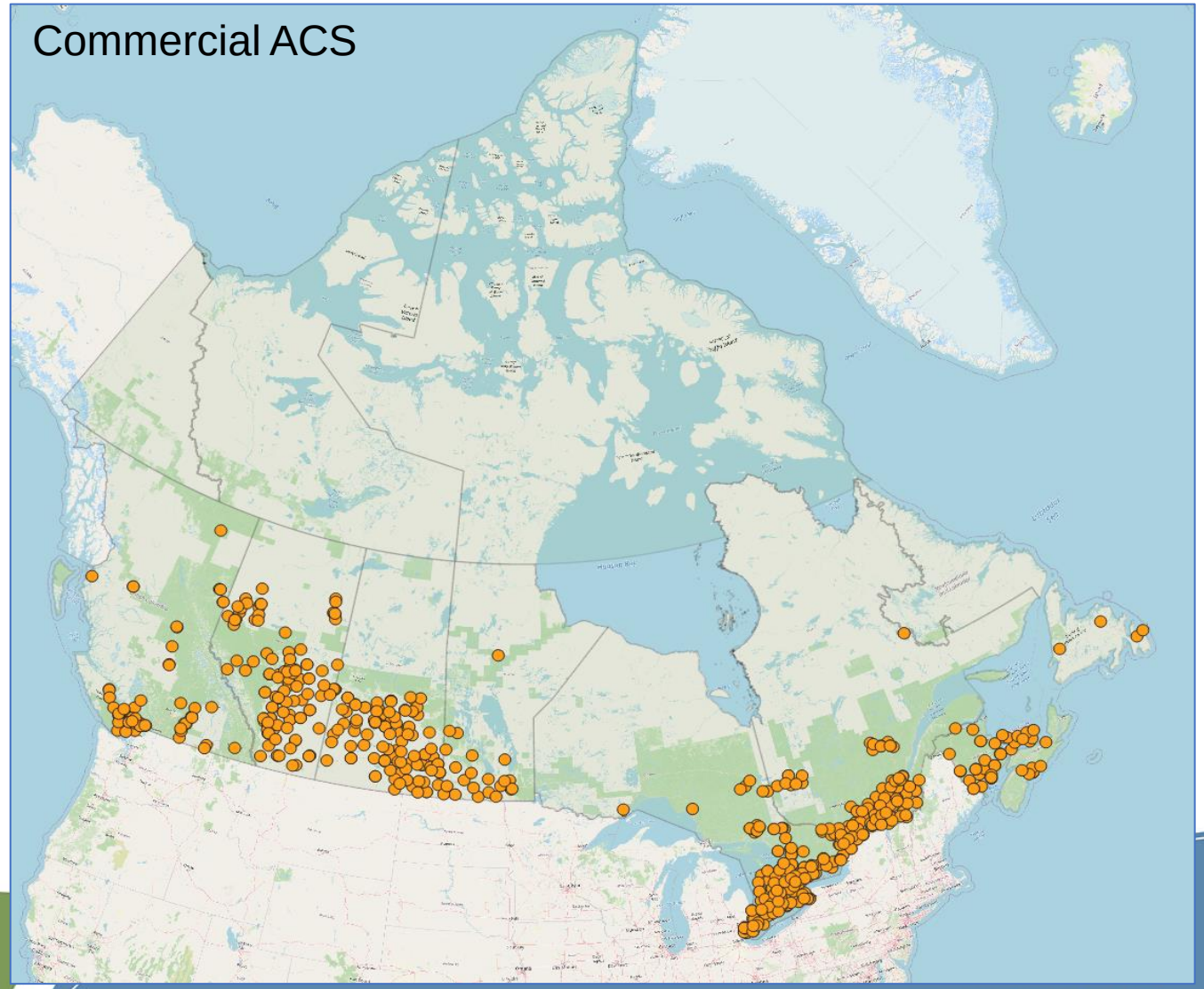
N (metres)		Published date Project ID
-29.707	274.993	2023-09-05 M18-020

VN (mm/year)	VH (mm/year)	Equipot. of geoid model (W_0, m^2s^{-2})
-0.20	0.69	n/a

Public ACS & CBN's

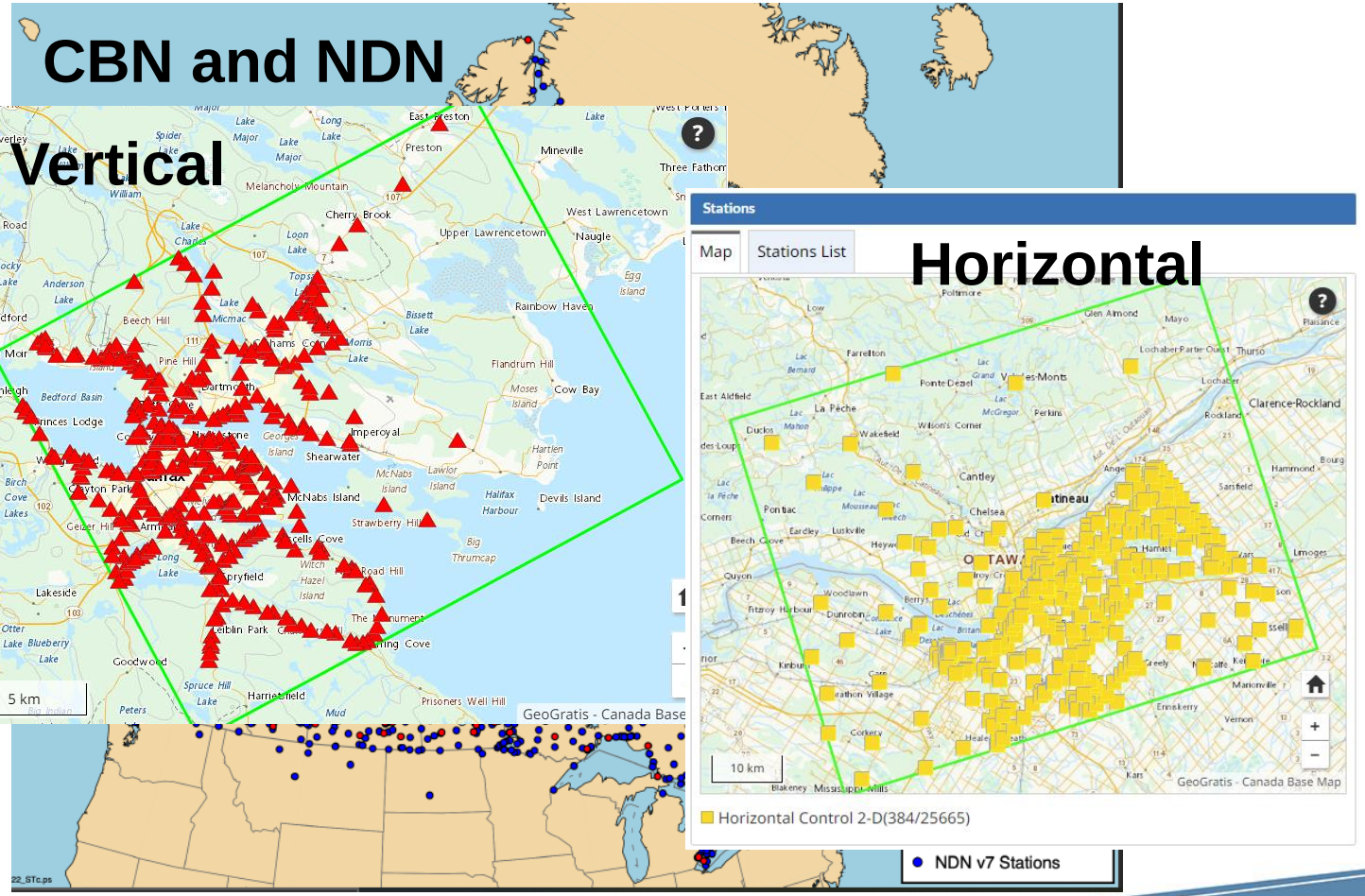
Working in the modernized CSRS: coordinates and velocities – active control

- Coordinates for RTK networks will be provided in NATRF2022
- Continued RTK compliance program which will be in NATRF2022 at some future date
- Providers will decide how to support NAD83 in the future



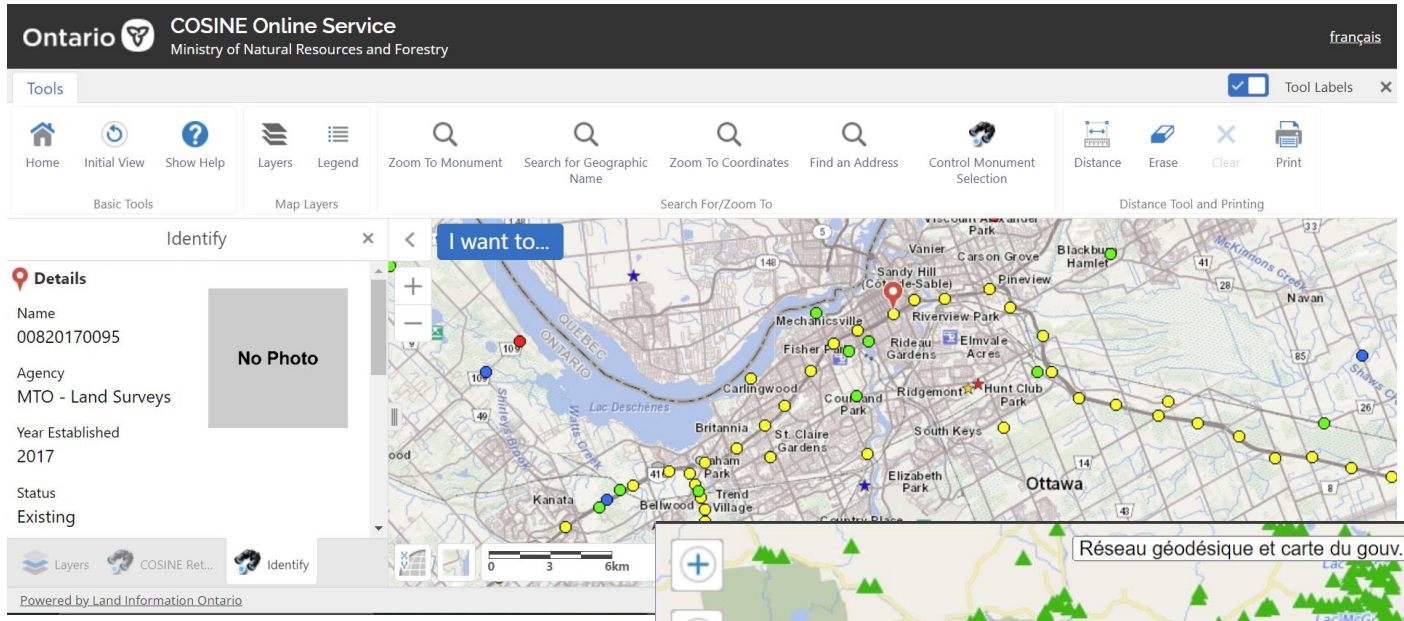
Working in the modernized CSRS: coordinates and velocities – passive control

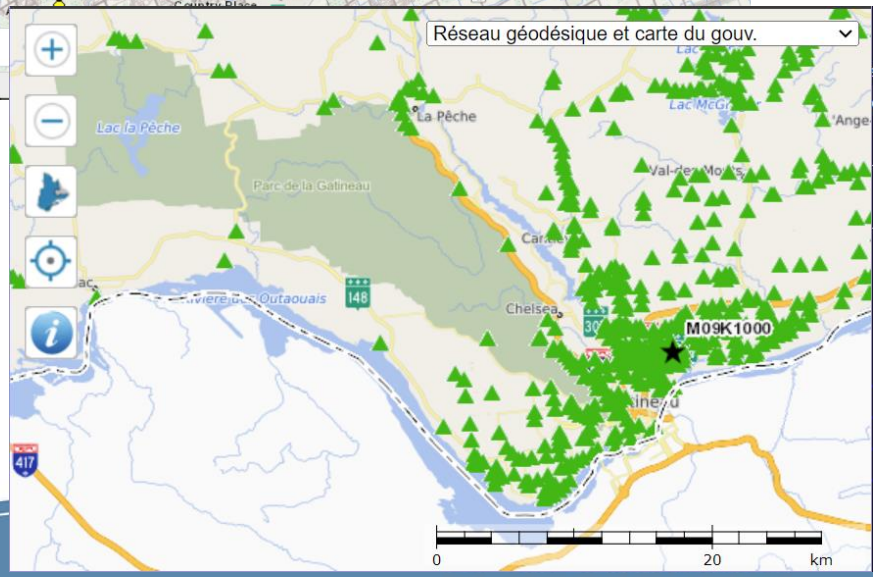
- Passive control is not physically maintained federally
- A re-adjustment of the National Densification Network (NDN) has recently been completed using the GNSS observations collected since 1994
- 3D networks (CBN and NDN) will be transformed to NATRF2022



Working in the modernized CSRS: coordinates and velocities – passive control

- Passive control is mostly supplied by provincial and municipal jurisdictions through a variety of dissemination methods
- Requirements and plans for modernization of passive control vary greatly in each jurisdiction (Part 3)



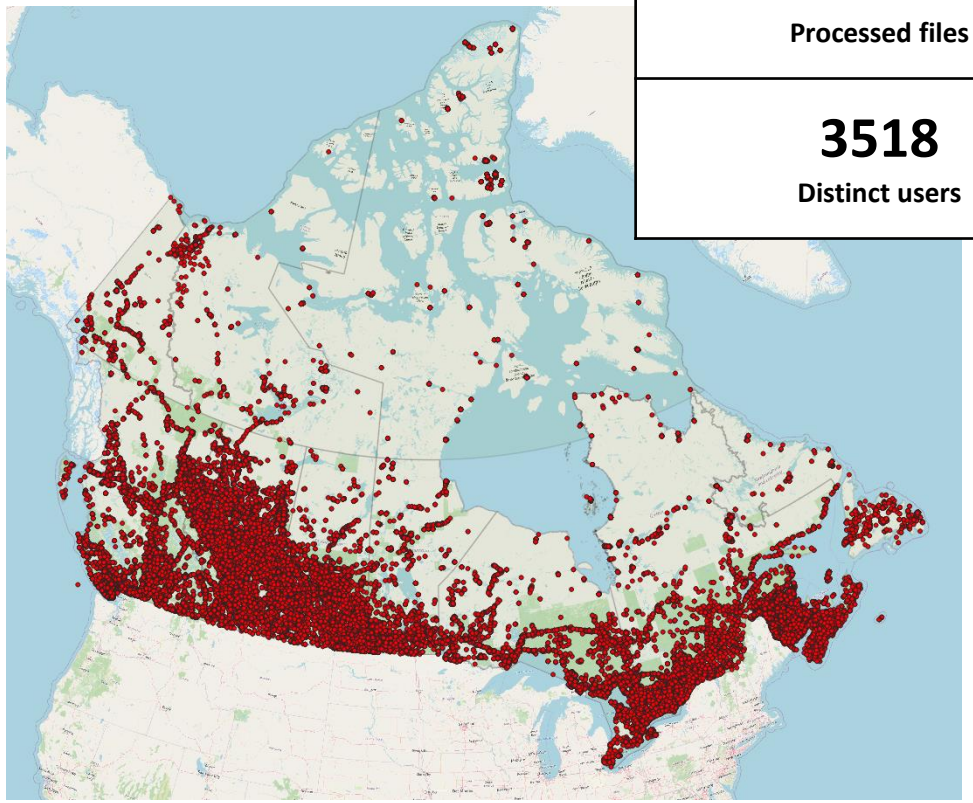


Geodetic Control Coordinates

Depiction of all horizontal control points integrated with the NAD83(CSRS98) datum for the province of Saskatchewan. Product Sample

Working in the modernized CSRS: CSRS-PPP

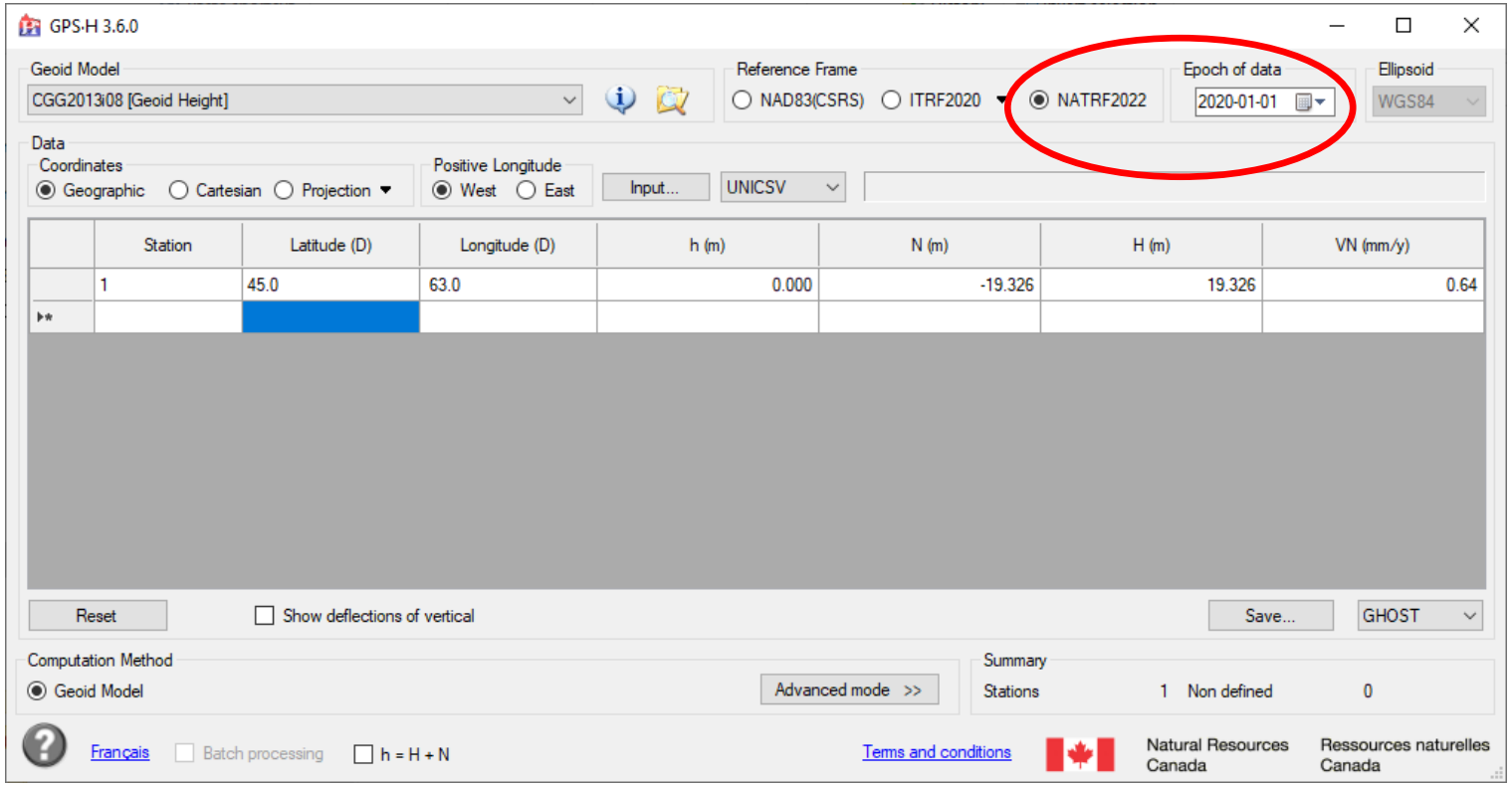
- Used extensively, particularly in remote areas and where passive control is not maintained
  - Allows users to set their own survey control
- Will include support for NATRF2022 and CGVD2013(GEOID2022) by 2025
- Currently supports GPS & GLONASS; support for Galileo is planned for late 2024



2022 CSRS-PPP Usage in Canada
216239 Processed files
3518 Distinct users

Working in the modernized CSRS: transformation tools

- TRX and GPS-H can be accessed as web applications, downloaded and installed on a Windows PC, or directly through our CSRS API
- Tools will be upgraded to support NATRF2022, CGVD2013(GEOID2022), and the updated national deformation model (IFDM2022) by 2025



Phased Roll out of Products

NATRF2022

- **ITRF2020** → **available now**
- **NAD83(CSRS) v8** → **early 2024**
  - Full reprocessing of GNSS observation data, beta for NATRF2022
- **EPP2022** → **2024**
  - CGS/NGS common N.A. plate rotation model
  - Defines the NATRF2022 reference frame
- **NATRF2022 coordinates & velocities** → **mid- to late 2025**

Phased Roll out of Products

NATRF2022

- **NAD83VGv8** → **mid 2024**
  - Velocity model, in current grid format
  - Possible IFDM2022 (beta) when transformed to NATRF2022
- **IFDM2022** → **2025**
  - Velocities only in 2025
  - More complex motions later

Phased Roll out of Products

CGVD2013

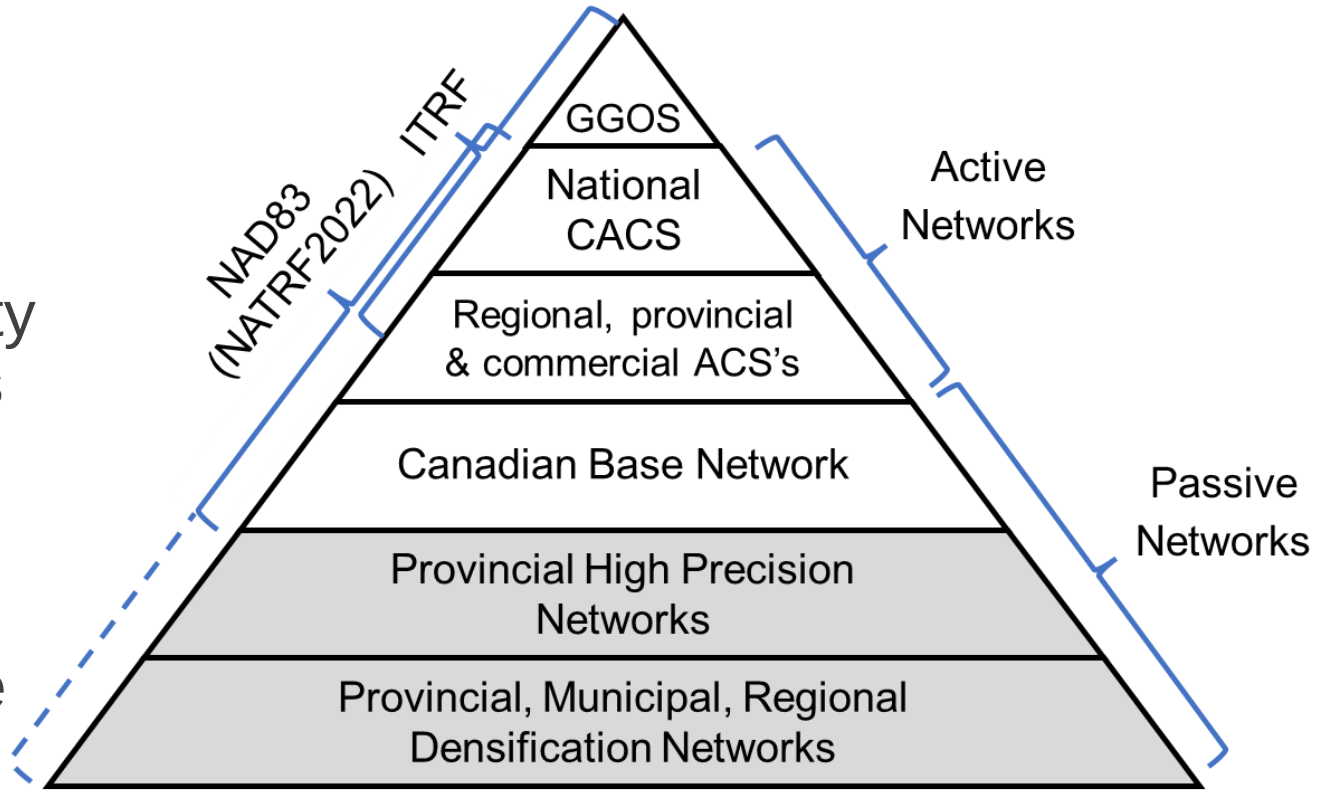
- **GEOID2020 (alpha)** → **early 2024**
  - On NGS alpha products website
- **GEOID2022 (beta)** → **summer 2024**
- **GEOID2022** → **mid- to late 2025**
- **CGVD2013(GEOID2022)** → **late 2025**

Part 3 – Unifying reference frames in Canada

- National goals & roadmap
- Modernization options (georeferencing & geospatial)
- Discussion

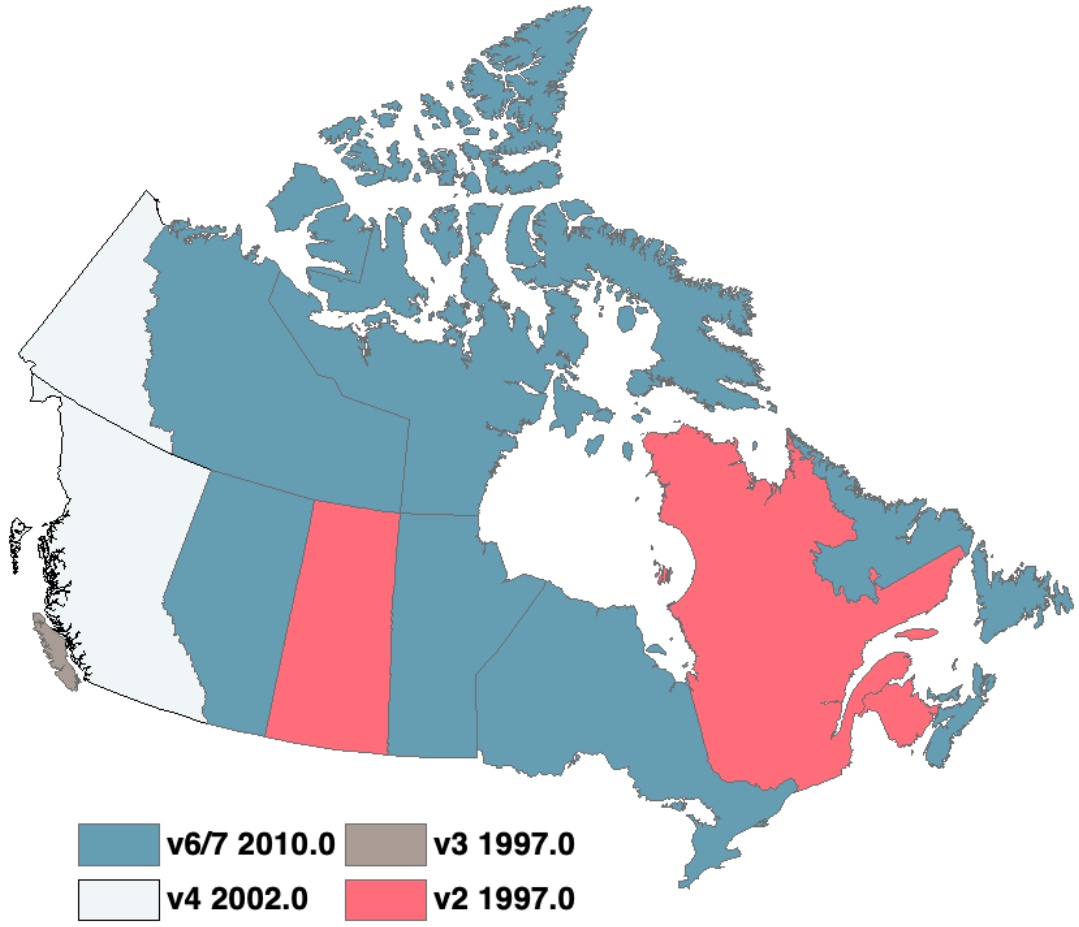
Geodetic services are a shared responsibility in Canada

- Defining the reference system is a federal mandate (NRCan/SGB/CGS)
- Provinces have the authority to regulate reference system usage in their jurisdictions, and the responsibility to provide control network coordinates
- Delivering the reference frame is coordinated through the **CGRSC (Canadian Geodetic Reference System Committee),** a subcommittee of CCOG (the Canada Council on Geomatics) and chaired by CGS



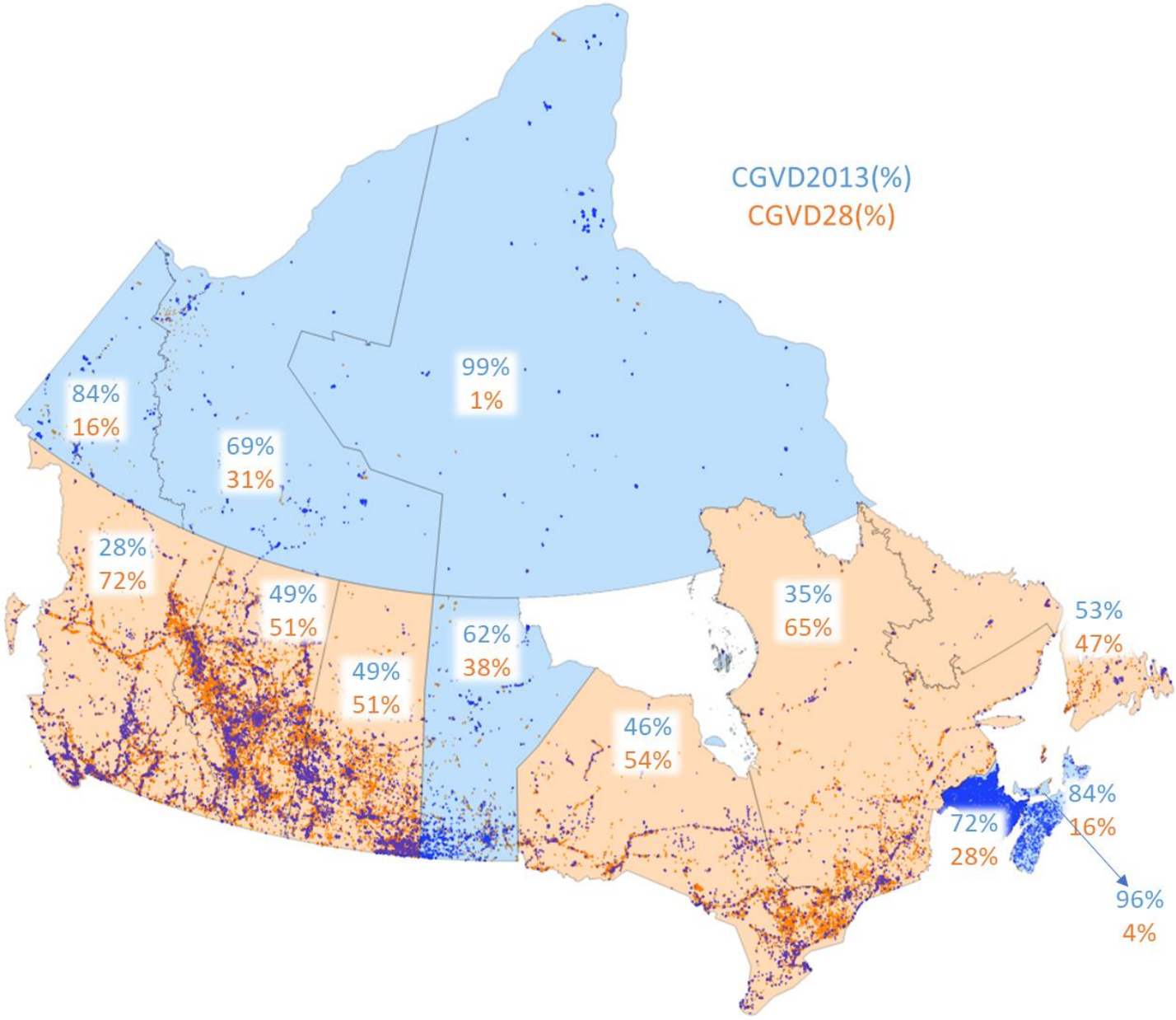
Modernization as unification opportunity

- Different NAD83(CSRS) versions across Canada
- Differences between versions and epochs can be up to several cm – risk of blunder unless properly addressed
- Confusing when working across provinces and for commercial services
- Different versions in use across jurisdictions; agencies need to provide multiple datasets
- Unification is needed to avoid 1-2 m differences in the future!



Modernization as unification opportunity

- Different versions of CGVD have been adopted across Canada
- 216,000 Canadian CSRS-PPP submissions in 2022 sorted by selected height system
- Both systems are in use in most provinces, but…
- …provincial adoption matters!



Reference frame unification in Canada

- CGRSC members have been working towards national unification since 2020
- Supported by a CCOG Resolution in October 2022
- CGRSC AGM (May 2023):
  - Most provinces agreed to work towards a detailed implementation plan
  - All provinces present considered a goal of unification by 2030 achievable

Whereas the United States plans to adopt new reference frames (NATRF2022[1] and NAPGD2022[2]) in 2025 and Natural Resources Canada (NRCan) is collaborating with U.S. officials to ensure compatibility at the international border, and;

Whereas CCOG subcommittees, the CGRSC and the Cadastral Forum, confirm a willingness to adopt NATRF2022 as a unified geometric reference frame within Canada, and;

Whereas the new US height system (NAPGD2022) will be compatible with the existing Canadian height system (CGVD2013[3]), and;

Whereas NRCan will work to ensure that tools are available for CGRSC and Cadastral Forum members and their stakeholders to update data sets as part of migration towards NATRF2022, and;

Whereas migration to new datums is expected to take several years, and capacity to perform the migration will require new or additional resources in many jurisdictions;

Be it resolved that the CCOG accepts and endorses these measures and encourages all Provincial jurisdictions to promote and facilitate preparation for the adoption of unified reference frames for Canada.

CCOG Resolution (October 2022)

Reference frame unification in Canada

- The CGRSC Unified Reference Frame Task Team has developed a Modernization Roadmap
- Current efforts are focused on
  - Migrating geodetic control
    - Implementation plans for most provinces are being developed
  - Considerations for supporting the migration of geospatial datasets
  - Updating regulatory dependencies
  - Stakeholder outreach (including municipalities)

NATRF2022 / CGVD2013

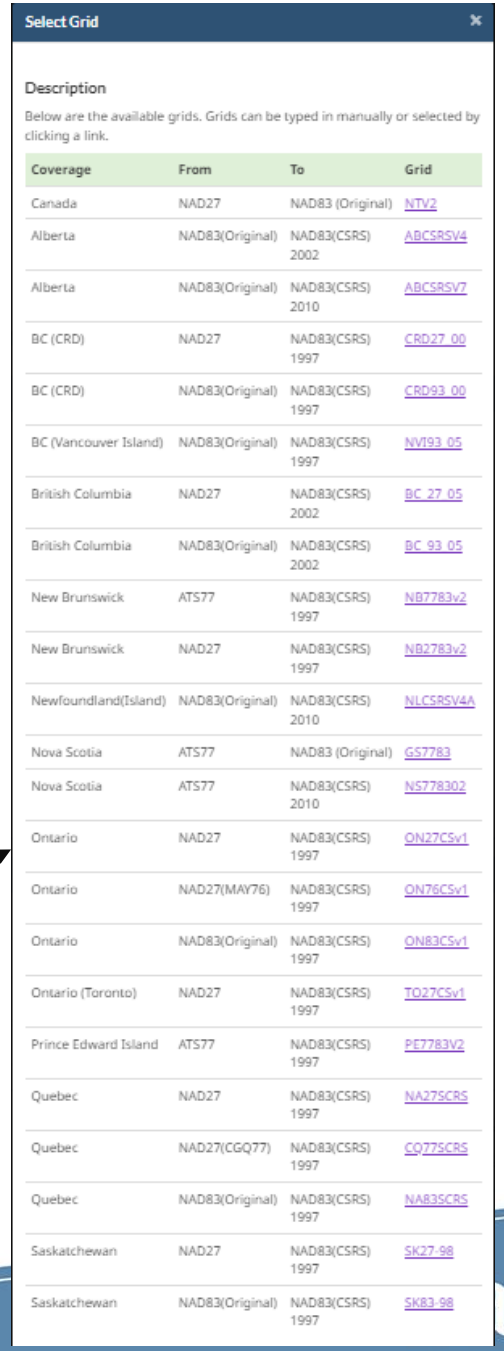
Migrating passive geodetic control

Most provinces have a draft migration plan in place which considers their accuracy requirements, current context, resources, and expertise

- Options for migrating passive control in order of increasing accuracy (and cost):
  - **Transform**: use transformation software like TRX to estimate new coordinates in NATRF2022 (quality?)
  - **Re-adjust**: using existing observations, re-compute NATRF2022 coordinates
  - **Re-survey**: collect new precise GNSS observations on passive monuments
- Some provinces are also looking at cost-effective ways to maintain (and expand) their HPN networks

Migrating geospatial datasets

- Requires the availability of commercial geospatial software tools which support the modernized CSRS
  - CGS/NGS hosted a Geospatial software developer's summit in 2022 to gauge their readiness
  - Will need support for dynamic datums to:
    - Migrate existing data layers from NAD83(CSRS) epochs 1997 and 2010 to NATRF2022 epoch 2020 (e.g., cadastral parcels, lidar datasets, road networks)
    - Work in the modernized CSRS and efficiently combine data layers from different sources and epochs
- Support to migrate from legacy datums (e.g. NAD83(Original)) to NATRF2022 may also be needed
  - **Gridshift:** NAD83(original) ⟺ NAD83(CSRS) ⇢ NATRF2022 (Accuracy? and Availability?)



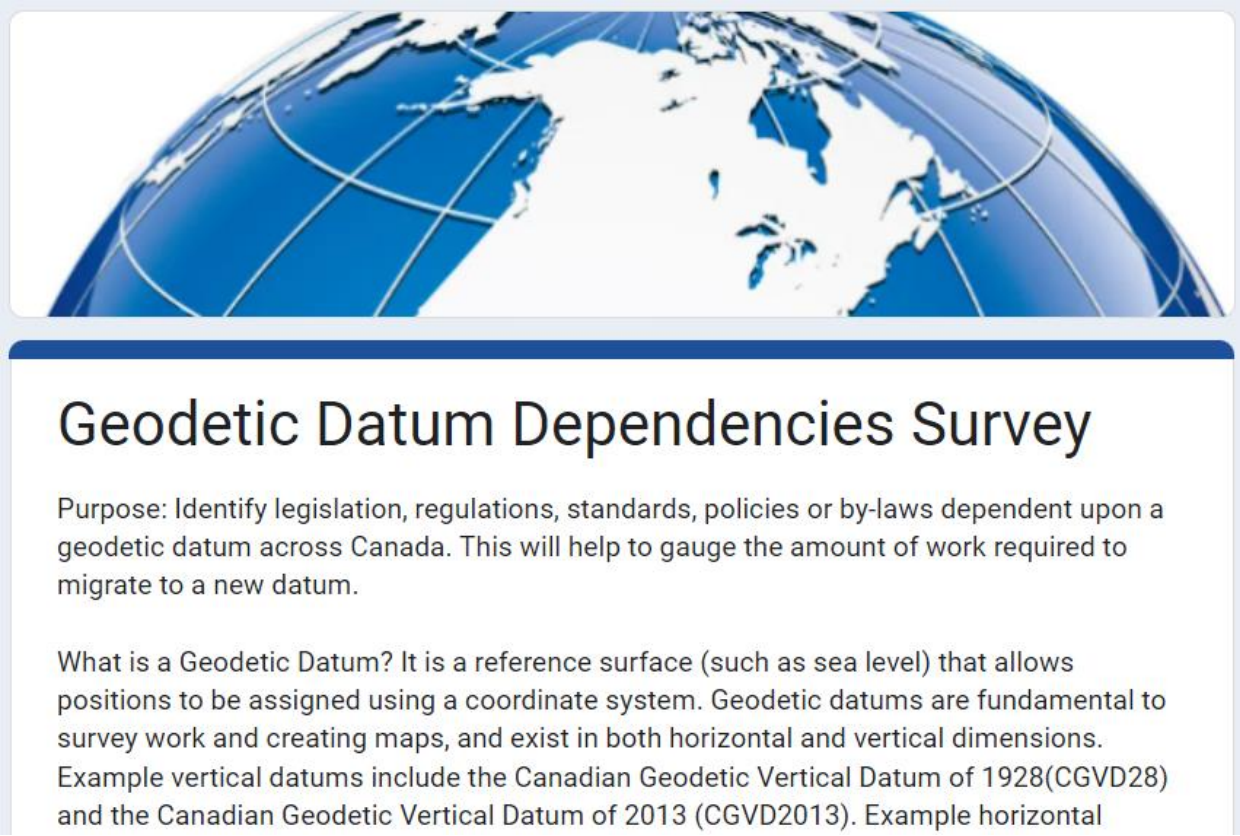
Select Grid

Description

Below are the available grids. Grids can be typed in manually or selected by clicking a link.

Coverage	From	To	Grid
Canada	NAD27	NAD83 (Original)	NTV2
Alberta	NAD83(Original)	NAD83(CSRS) 2002	ABCSRSV4
Alberta	NAD83(Original)	NAD83(CSRS) 2010	ABCSRSV7
BC (CRD)	NAD27	NAD83(CSRS) 1997	CRD27_00
BC (CRD)	NAD83(Original)	NAD83(CSRS) 1997	CRD93_00
BC (Vancouver Island)	NAD83(Original)	NAD83(CSRS) 1997	NVI93_05
British Columbia	NAD27	NAD83(CSRS) 2002	BC_27_05
British Columbia	NAD83(Original)	NAD83(CSRS) 2002	BC_93_05
New Brunswick	ATS77	NAD83(CSRS) 1997	NB7783v2
New Brunswick	NAD27	NAD83(CSRS) 1997	NB2783v2
Newfoundland(Island)	NAD83(Original)	NAD83(CSRS) 2010	NLCSRSV4A
Nova Scotia	ATS77	NAD83 (Original)	GS7783
Nova Scotia	ATS77	NAD83(CSRS) 2010	NS778302
Ontario	NAD27	NAD83(CSRS) 1997	ON27CSv1
Ontario	NAD27(MAY76)	NAD83(CSRS) 1997	ON76CSv1
Ontario	NAD83(Original)	NAD83(CSRS) 1997	ON83CSv1
Ontario (Toronto)	NAD27	NAD83(CSRS) 1997	TO27CSv1
Prince Edward Island	ATS77	NAD83(CSRS) 1997	PE7783V2
Quebec	NAD27	NAD83(CSRS) 1997	NA27SCRS
Quebec	NAD27(CGQ77)	NAD83(CSRS) 1997	CQ77SCRS
Quebec	NAD83(Original)	NAD83(CSRS) 1997	NA83SCRS
Saskatchewan	NAD27	NAD83(CSRS) 1997	SK27-98
Saskatchewan	NAD83(Original)	NAD83(CSRS) 1997	SK83-98

Updating Regulatory Dependencies



- Survey launched in October 2022
- 209 responses received
- Wide variety of responses on the effort required to update regulatory dependencies
- Common responses included: provincial legislation/regulation, land surveys acts, municipal bylaws, standards of practice and contract specifications
- Common applications included: legal surveys, hydro & flood mapping, construction & engineering, natural resources, and climate regulations

Summary

- Canada and the US are modernizing their reference systems federally in 2025
- In Canada this means replacing NAD83 with NATRF2022 and updating CGVD2013
- Working in the modernized CSRS will be very similar to working in NAD83(CSRS); same tools and services; similar dynamic datums
- A unified adoption across Canada by 2030 is being planned through the CGRSC but will take significant effort

Additional resources

Publications:

- Erickson, C., Banham, G., Berg, R., Chessie J., Craymer, M., Donahue, B., Tardif, R., Thériault, Y., & Véronneau, M. ***The U.S. is replacing NAD83 with NATRF2022: what this means for Canada***. Geomatica. 73(3): 74-80. https://doi.org/10.1139/geomat-2019-0021

Online resources:

- **NGS website, 'New Datums: Replacing NAVD 88 and NAD 83'**
- **NRCan website, 'Geodetic reference systems in Canada'**
- **CGRSC website, reference system resources & NATRF2022 update**

Webinars:

- **NGS Webinars**
- **CGS webinar (ACLS, 2021-01): 'Modernization of the North American Reference System – The U.S. Plan and the Considerations for Canada'**
- **CGS webinar (ACLS, 2021-05): 'NAD83(CSRS): From Static to Dynamic'**
- **CGS webinar (ACLS, 2022-12): 'Height system modernization in Canada and North America'**
- **NGS/CGS summit (2022-11): 'Canada – U.S. Geospatial Software Developers Summit'**

Thank you!

Please reach out to us if you have comments or questions regarding reference system modernization

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CGRSC members