Integration of the Canadian Gravity Standardization Network with the Canadian Spatial Reference System: Challenges and Opportunities

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VERTICAL DEFORMATION RATES IN CANADA

An analysis of the GPS-determined time rate of change for sites of the Canadian Base Network (CBN)

Initiated in 1994, the Canadian Base Network (CBN) is a network of pillar monuments with forced-centering mounts for Global Positioning System (GPS) receiver antennae. Accurately positioned three-dimensionally with GPS, the CBN can serve as a monitoring network for deformation studies of the Canadian landmass. By combining nearly ten years of repeated multi-epoch (episodic) GPS measurements, we estimate velocities at the CBN sites to provide an increased spatial sampling of crustal deformation throughout Canada.

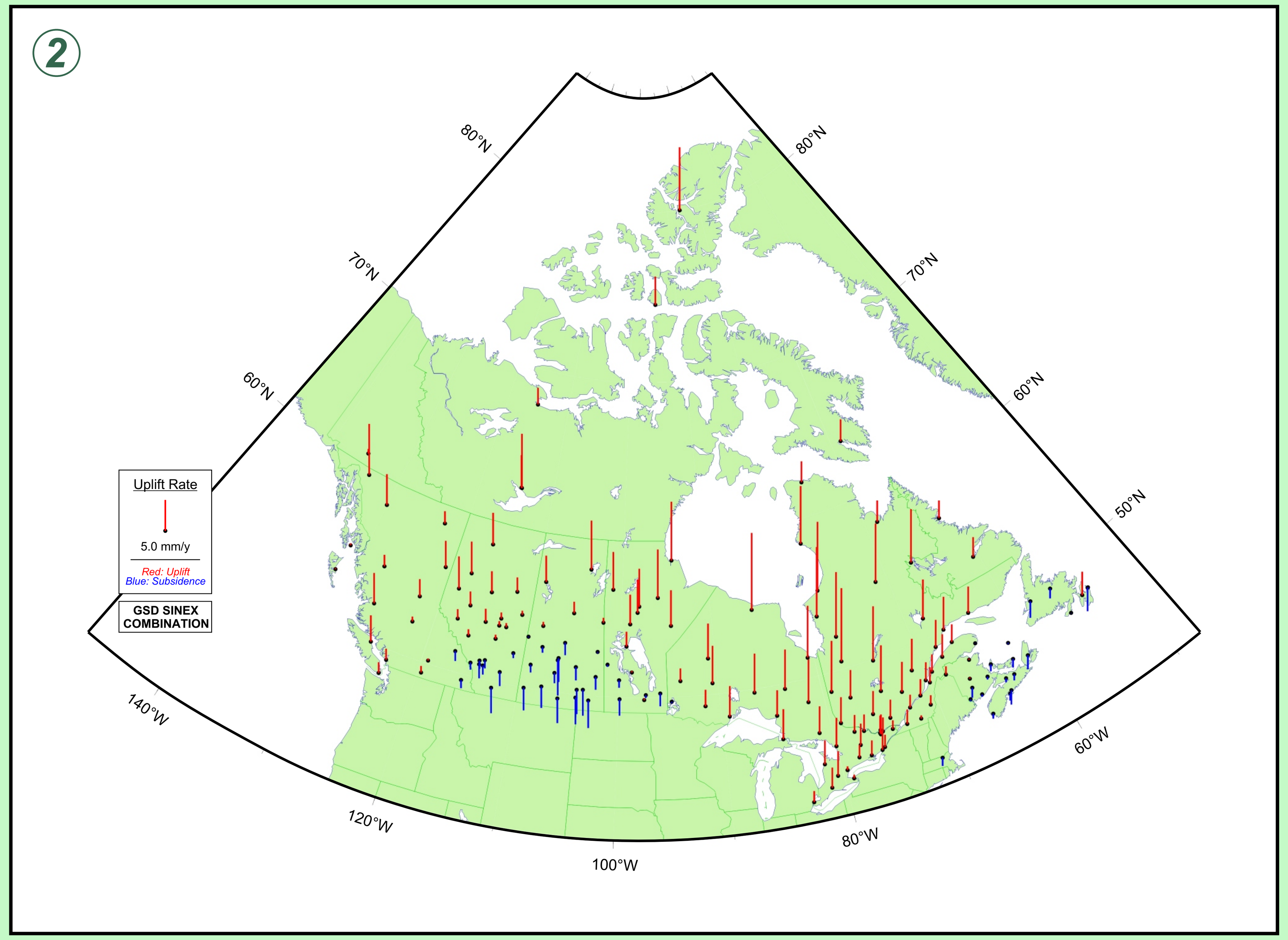
To determine individual station velocities, we systematically combine regional CBN solutions for each measurement epoch into a single Canada-wide, multi-epoch cumulative solution. In order to generate time series of consistent, high-accuracy coordinates for velocity estimation, it is necessary to ensure consistency in the realization of the reference frame. We accomplish this by aligning each of the individual CBN solutions to the IGS realization of ITRF using a subset of stations from a recent IGS cumulative solution for the IGS global network. Fortunately, there are many IGS stations in Canada and most were included in each regional CBN solution to strengthen the realization of the reference frame and ensure consistency between epochs. We also ensure consistent and realistic weighting of the individual CBN solutions through the estimation of variance components relative to the IGS global solution. After the individual CBN solutions are aligned and weighted, they are combined together in a simultaneous cumulative solution for velocities at each site.

Figure 1 *- Canadian Base Network (CBN) pillars in Québec.*

Figure 2 *- Observed CBN vertical rates.*
Preliminary results from the SINEX combination of CBN regional solutions in Canada exhibit a spatially coherent pattern of uplift consistent with the expected post-glacial rebound (PGR) signal.

Figure 3 *- Uncertainties of observed CBN vertical rates.*
Uncertainties (1-sigma) for the SINEX combination are shown.

Figure 4 *- Observed CBN vertical rates (contoured).*



CBN GPS PROCESSING

- ❖ Bernese GPS Software Version 4.x
- ❖ Double-differenced observations
- ❖ 30 second data sampling
- ❖ ≤10° elevation cut off
- ❖ Fixed precise orbits & ERPs (EMR/NRCan & IGS)
- ❖ Tropospheric zenith delays (every 2 hours)
- ❖ Niell mapping function (dry)
- ❖ No tropospheric gradients
- ❖ QIF ambiguity resolution
- ❖ No ocean loading model
- ❖ 1 IGS reference frame station constrained (fixed) (e.g. ALGO, DRAO, YELL)

CBN COMBINATIONS

Combining 36 individual CBN solutions (campaigns) from 1994 to 2004

Using SINEX combination software:

- GSD SINEX Software (vBDA) by Remi Ferland (used for official IGS global combinations)

Each CBN solution aligned to recent IGS cumulative solution (IGS05P41.snx) at epoch of solution:

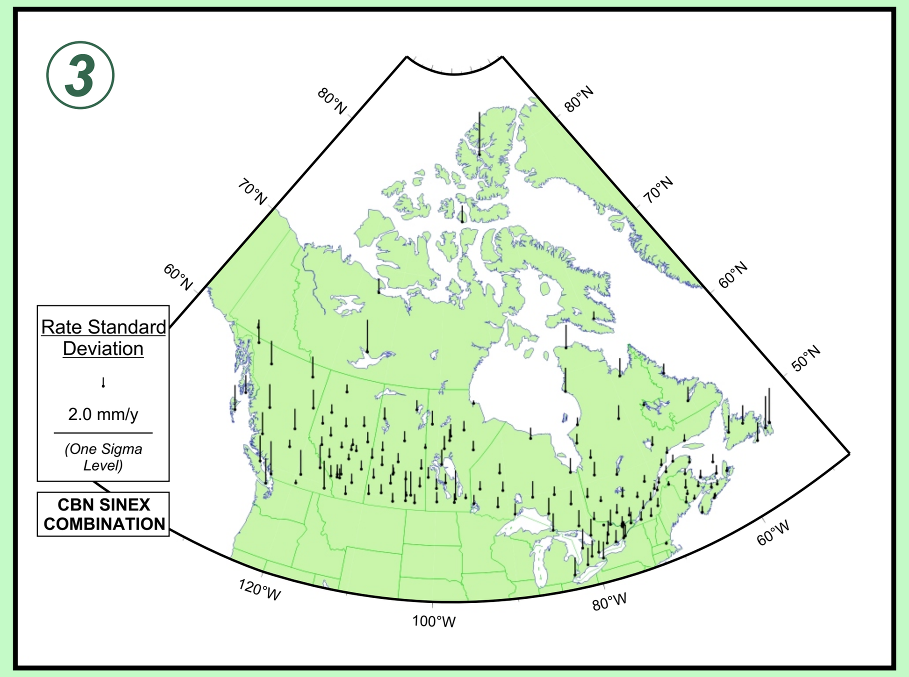
- "larger" networks (23 solutions): 3 translations, 3 rotations & scale change
- "smaller" networks (13 solutions): 3 translations

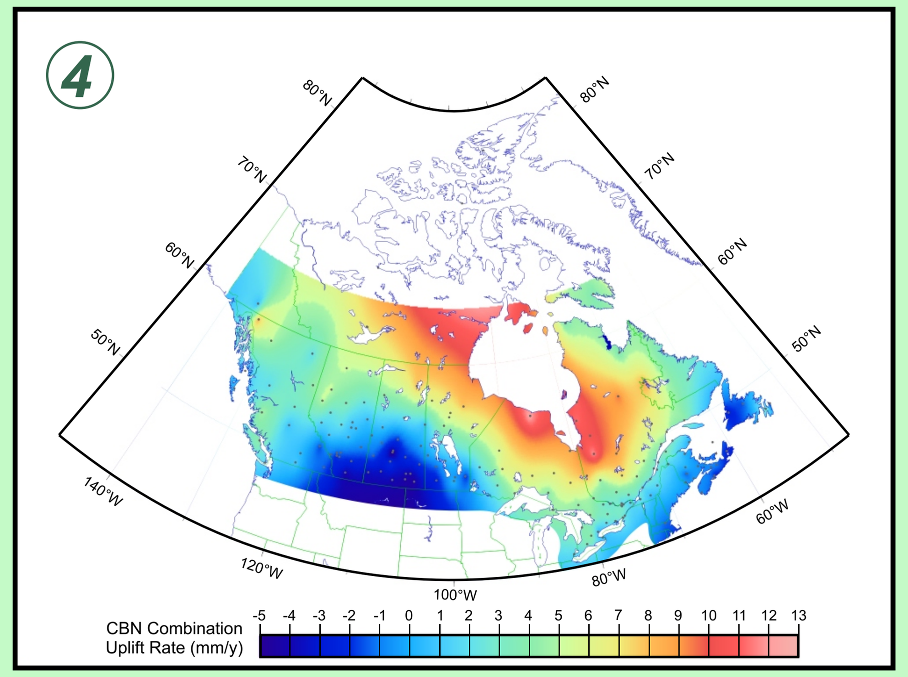
Covariance matrix of each CBN solution scaled by WRMS of residuals from alignment

Geocentre parameters added to each CBN solution (to allow solutions to translate during combination)

All (scaled) CBN solutions combined together (summation of normals) and velocities estimated

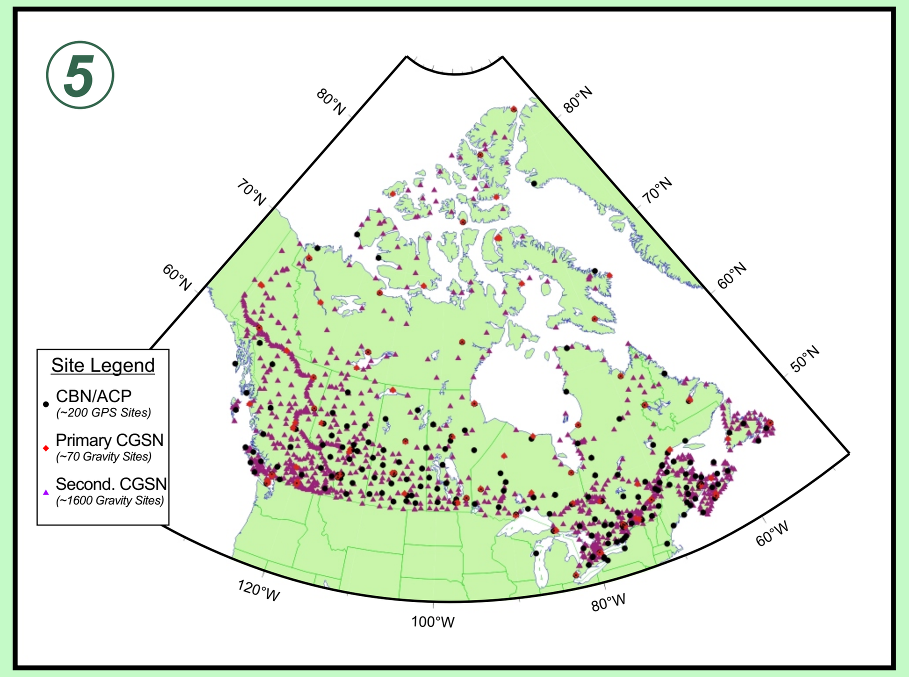
Single station minimum constraint added using the IGS cumulative solution coordinates and velocities of ALGO





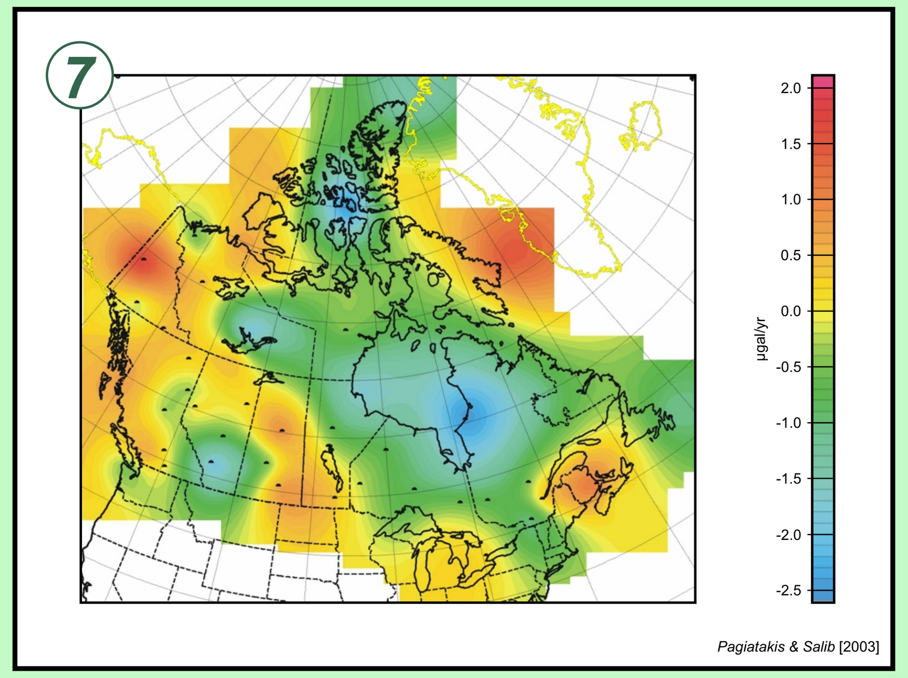
The primary role of the Geodetic Survey Division (GSD) is to maintain, continuously improve, and facilitate efficient access to the Canadian Spatial Reference System (CSRS). This includes the responsibility to maintain the Canadian Gravity Standardization Net (CGSN) that provides datum control for gravity observations across Canada. The current primary network and complementary control stations of the CGSN have been mainly established and maintained using relative gravimetry linked to only a few absolute gravity stations. However, with recent improvements in absolute gravimeters it has become tenable to modernize and subsequently maintain the CGSN utilizing primarily absolute gravimetry (AG) techniques.

Additionally, as measurement and processing accuracies have increased, the Division is now in an era in which the time-variability of our observations (positions and gravity) must be considered. In order to better contribute to the definition of the vertical component of a highly accurate, multi-purpose, active and integrated CSRS, the GSD is developing a set of recommendations for CGSN integration with geometric reference stations (VLBI, continuous and episodic GPS). The establishment and maintenance of this modernized CGSN will be commensurate with international standards and trends. To meet the above goals, efforts are now underway to densify the array of absolute gravity observations in Canada.



MODERNIZATION OF THE CGSN

Moving towards to co-location of gravity datum control sites with CSRS positioning reference stations



Within Canada, the most significant movement for most of the landmass will be vertical motion, as demonstrated by current analyses. It is therefore critical to be able to monitor and confirm height variations over time. Absolute gravimetry, which is independent of GPS, can also play a complimentary role in detecting vertical movements through repeated observations at certain sites. These capabilities should prove useful to the maintenance of a new gravity-based height-reference system.

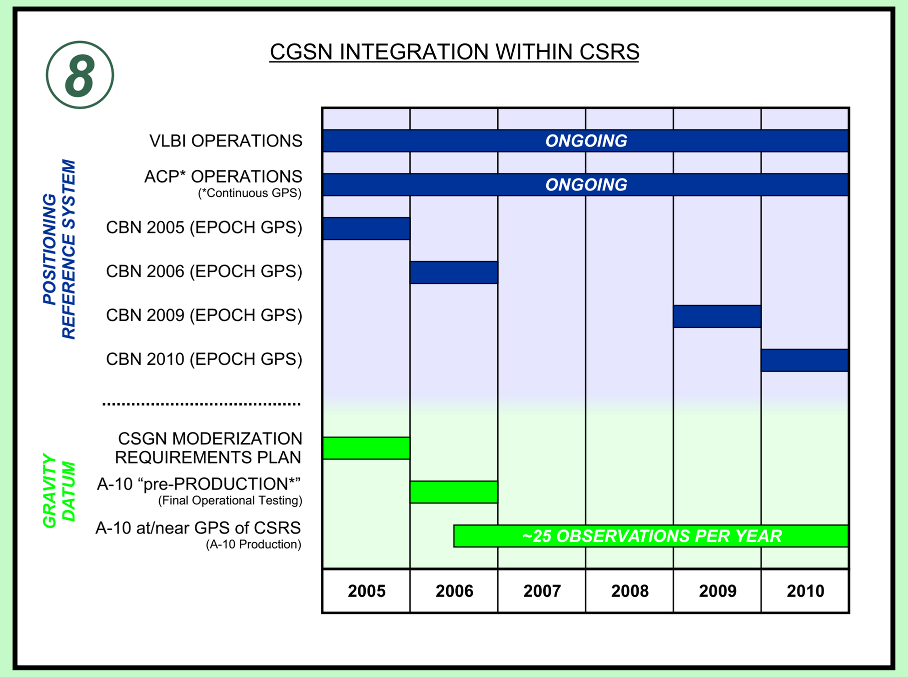
To further evaluate the long-term stability of AG measurements, an array of absolute gravity sites has been established in eastern Canada. These sites are all co-located with high-precision GPS and also serve as a regional monitoring network for deformation studies. Preliminary results exhibit general agreement among the uplift rates for GPS vertical velocities, gravity trends, and predictions of vertical crustal motion from postglacial rebound models.

Figure 5 *- Distribution of CGSN gravity sites.* Future gravity control points will be co-located at GPS sites.

Figure 6 *- A-10 (S/N 003) undergoing testing in Québec.* The A-10 absolute gravimeter (AG) is the expected "workhorse" for CGSN modernization and subsequent monitoring of the gravity datum.

Figure 7 *- Time rate of change of gravity from historical relative-gravity observations of the CGSN.* This "g-dot" map exhibits a spatial pattern largely similar to that expected from the observed uplift rates (after *Pagiatakis, S.D. & P. Salib* [2003]: *JGR*, *108* (B9); image courtesy of Phil Salib).

Figure 8 *- Draft operations time-line for CGSN modernization.* A suitable (*TBD*) number of new gravity datum points will be established and subsequently revisited with an AG (*e.g.* A-10).



Acknowledgements

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Canadian Spatial Reference System
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