



Canadian Height Reference System Modernization: Rationale, Status and Plans

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What is Height Modernization?



A transformative project of the Canadian Spatial Reference Service to:

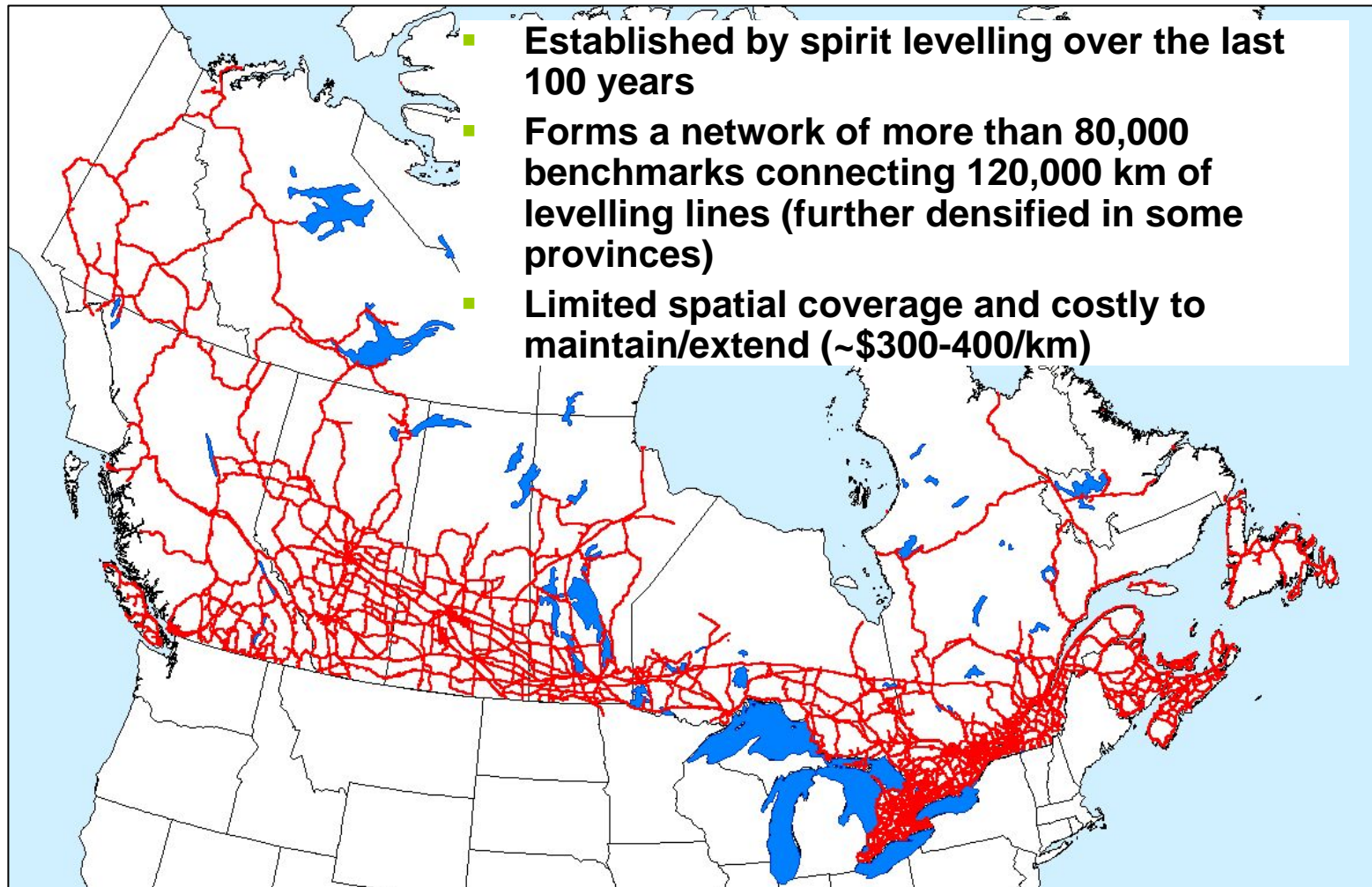
- Develop, implement and promote a new height reference system for Canada.
- Realise a new vertical datum by geoid modeling, rather than by geodetic levelling.
- Provide a consistent vertical datum everywhere across the country.
- Facilitate the measurement of mean sea level elevations using the Global Positioning System (GPS) and emerging Global Navigation Satellite System (GNSS) technologies.
- Reduce user dependency on monumented networks and the cost of their physical maintenance.

Why Modernize the Height Reference System?



- **Benefit from new technologies**
 - Global Navigation Satellite Systems (GPS, GLONASS, Galileo)
 - Satellite gravity missions (CHAMP, GRACE and GOCE)
- **Offer full coverage of the Canadian territory**
- **Reduce cost of maintaining the existing first-order levelling network and overcome difficulty of extending it to the North**
- **Overcome limitations caused by existing distortions (systematic errors and blunders) in the current standard, the Canadian Geodetic Vertical Datum of 1928 (CGVD28)**
- **Realise operational efficiencies in user applications and economies in reference frame provision**
- **Move towards the unification of the horizontal and vertical networks into NAD83(CSRS)**

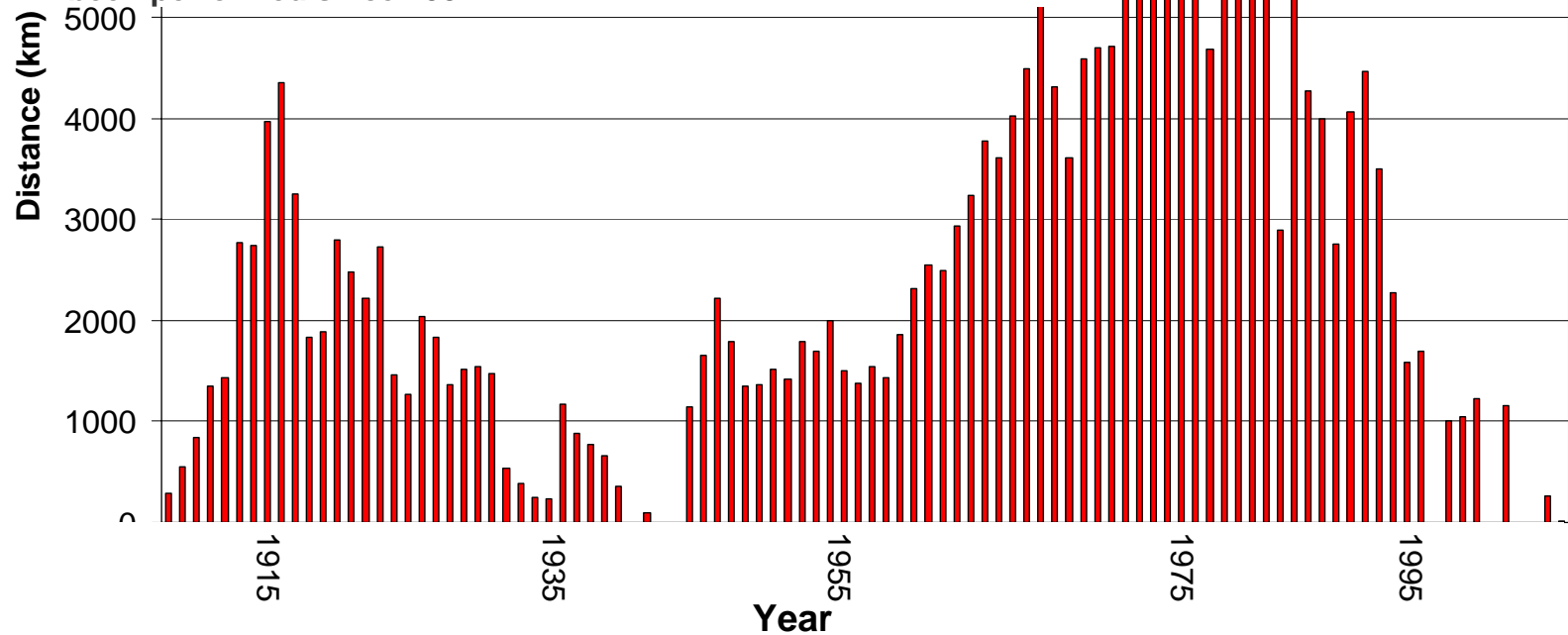
Coverage of the first-order levelling network in Canada



First-order levelling surveys (1907-2006)



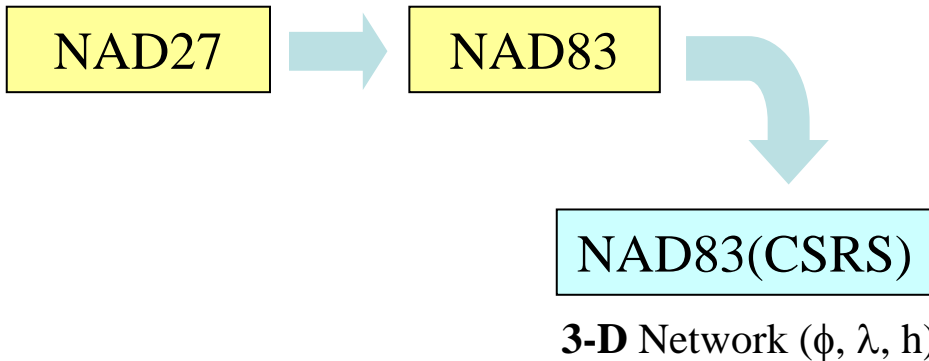
- From 1972 to 2000, the first-order vertical network was almost entirely re-surveyed with about 115,000 kms of levelling lines observed
- For 30 years until the early 1990's, GSD carried out an average of 4000 kms of levelling annually (~65% maintenance and 35% network expansion)
- Since the mid-1990's, a steady decline has occurred and only minimal targeted levelling to support geoid model validation has been performed since 2001.



Unification of horizontal and vertical networks

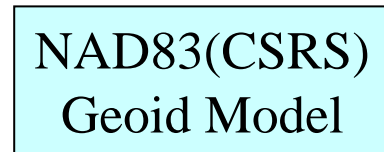


Horizontal Network (ϕ, λ)

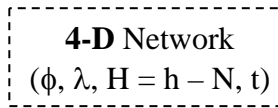


Now

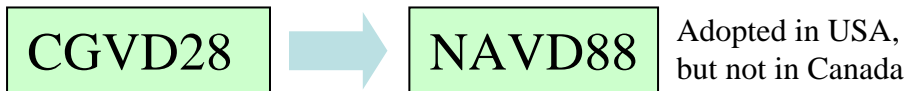
3-D Network
($\phi, \lambda, H = h - N$)



Future



Vertical network (H)



Main Components of Height Modernization Project?



Geoid model and 3D reference network improvement

- Use latest gravity database (terrestrial and spatial) and digital elevations models;
- Conduct targeted GPS and levelling surveys for geoid validation;
- Update reference network 3D coordinates and estimate vertical velocities;
- Develop conversion tools to facilitate user transition from CGVD28 to the new vertical datum.

Implementation and adoption (in collaboration with *CGRSC)

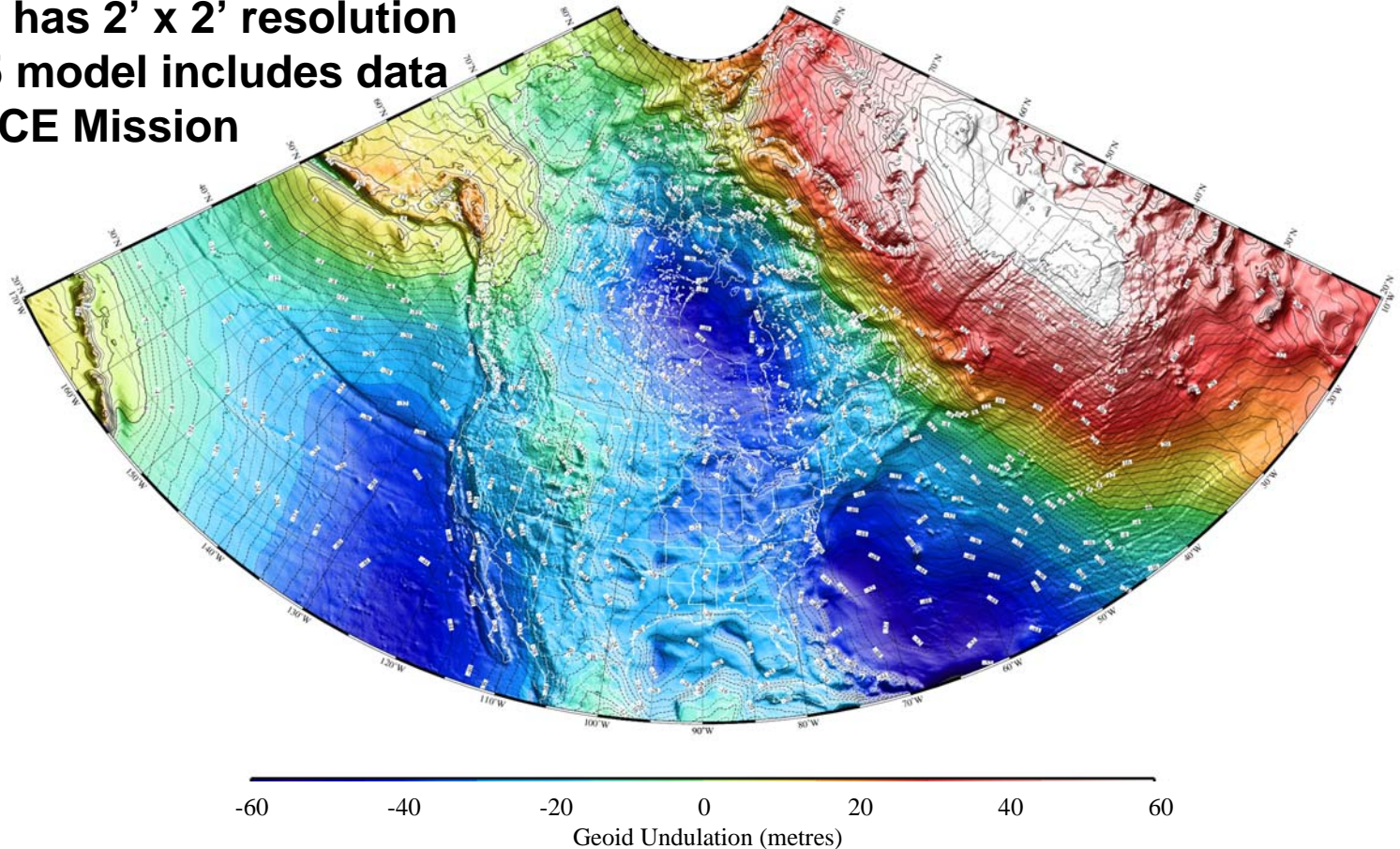
- consult with stakeholders (2006 HAL Report);
- develop implementation and communication plans;
- prepare educational materials;
- promote the benefits of a new vertical datum through WEB site, conferences and workshops.

* *The Canadian Geodetic Reference System Committee of the Canadian Council on Geomatics (CCOG)*

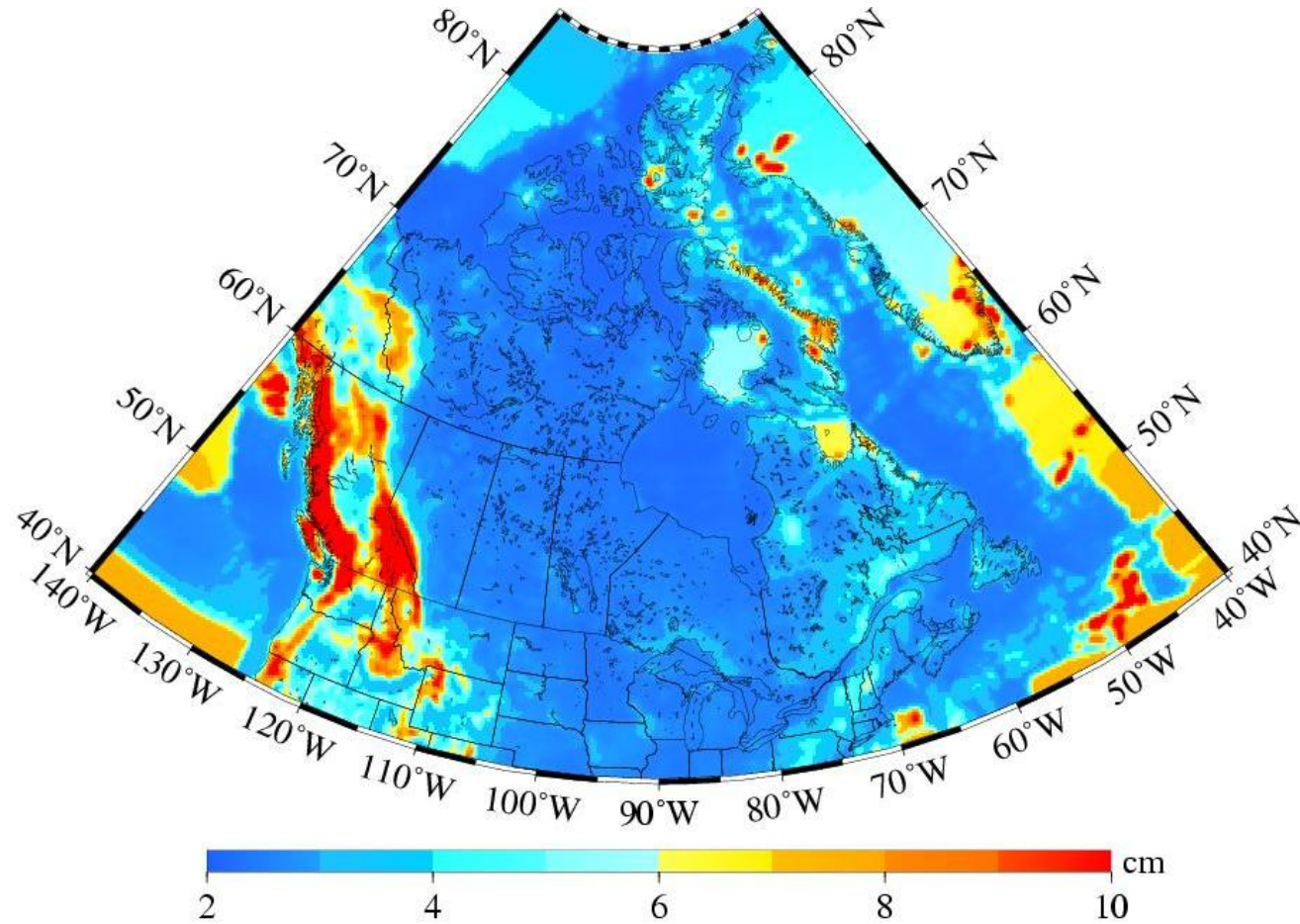
Canadian Gravimetric Geoid (CGG2005)



- Geoid undulations vary within 120 m. Canada-wide
- CGG grid has 2' x 2' resolution
- CGG2005 model includes data from GRACE Mission



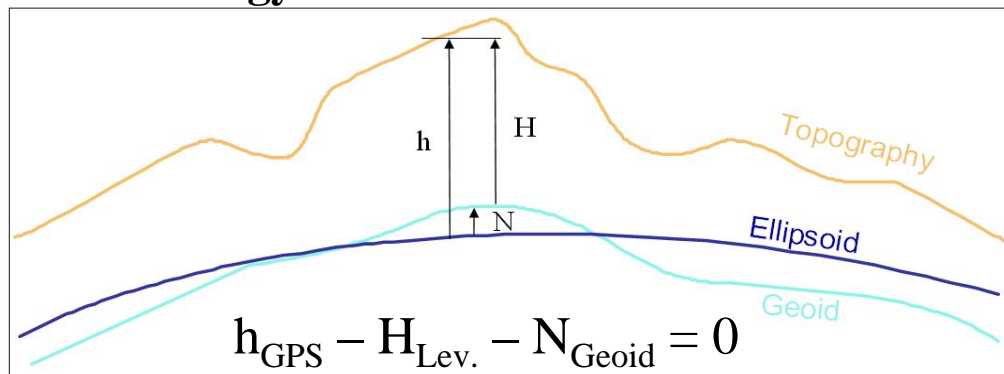
Formal Precision of Geoid Model



CGG2005 Validation Methodology and Statistics



Methodology



GPS on BM in Canada (2274 points)



Statistics (cm)

Min.: -66.5

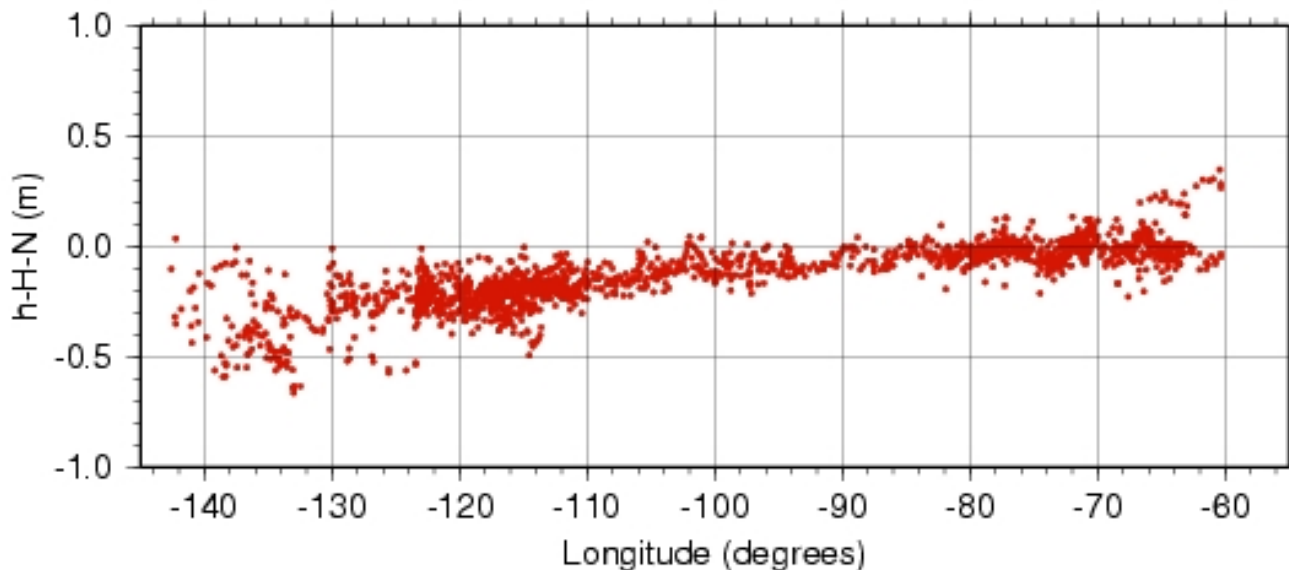
Max.: 34.6

Avg.: -14.9

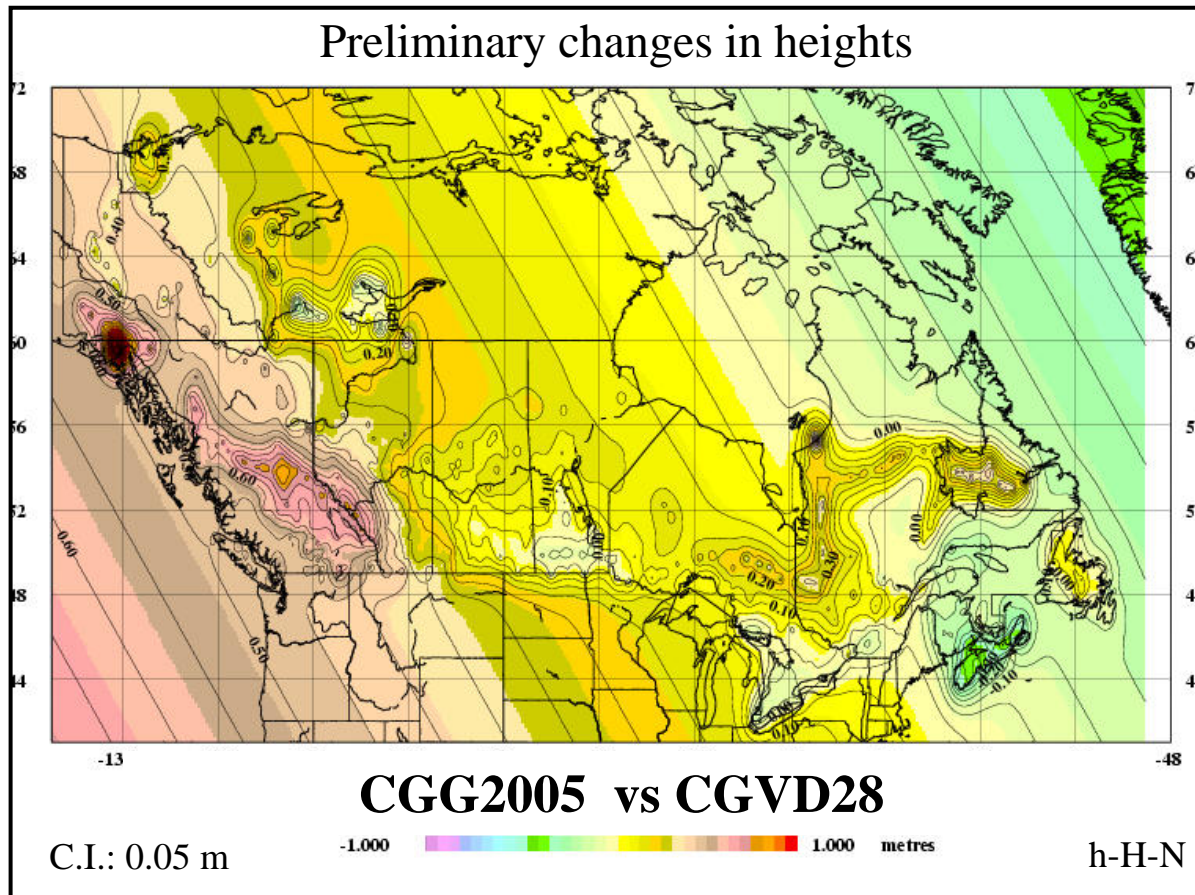
σ : 13.0

σ^* : 7.2

*after removing
linear trend



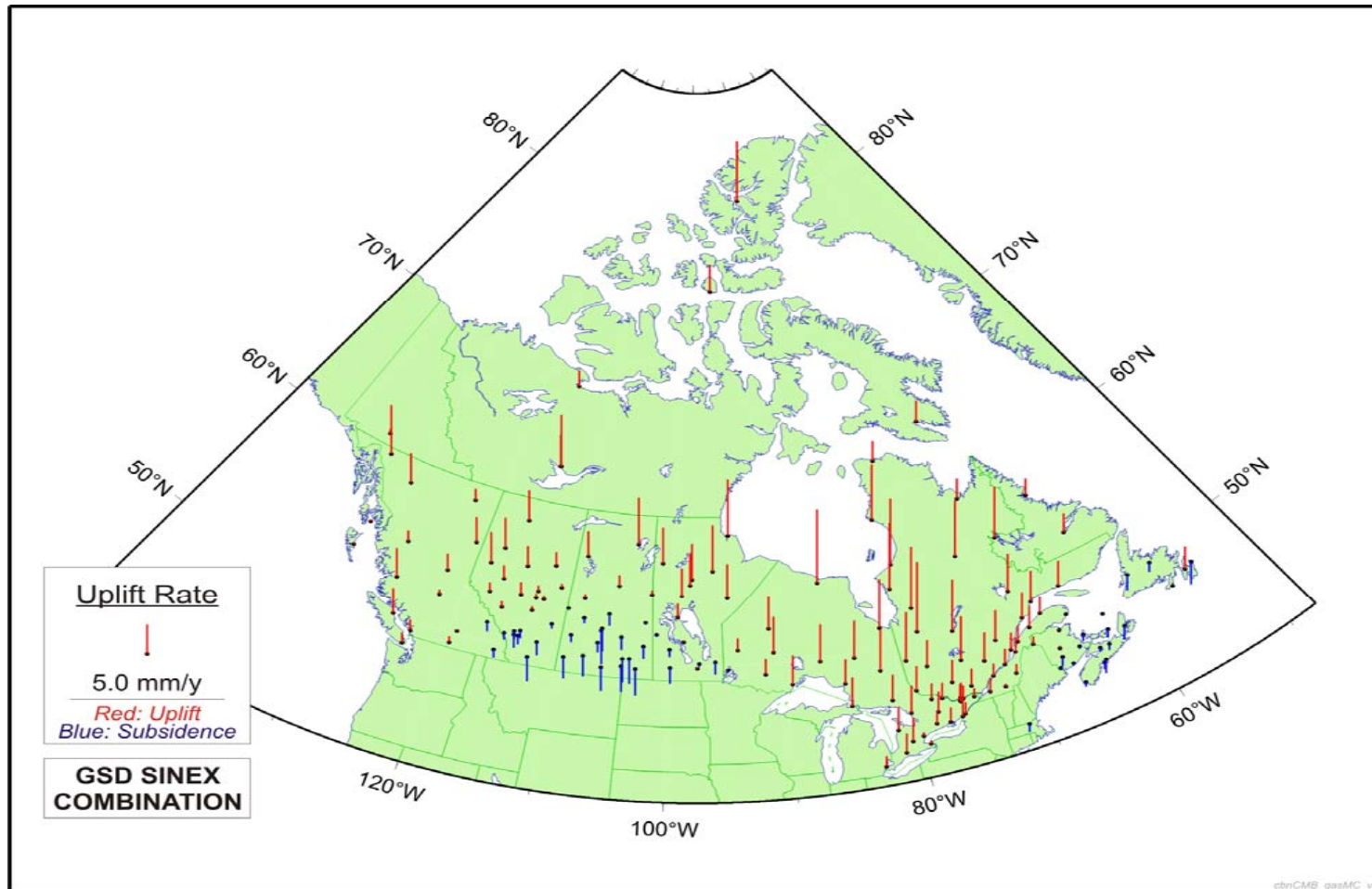
Differences between CGG2005 and CGVD28 (preliminary)



Preliminary changes in heights

St-John's:	-10 cm
Halifax:	-35 cm
Montreal:	-10 cm
Toronto:	-5 cm
Winnipeg:	-5 cm
Regina:	0 cm
Edmonton:	25 cm
Banff:	75 cm
Vancouver:	50 cm
Whitehorse:	60 cm

Vertical rates of 3D control (CBN)



Stakeholder Concerns (HAL Consultation)



- **A geoid model as reference**
 - Accuracy and long-term stability of the model;
 - Possibility of frequent updates with new realisations;
- **Differences between CGVD28 and CGG datums**
 - Possible confusion leading to errors in regions with centimetre level differences
- **Physical network degradation**
 - Reduced availability of monumented benchmarks (no more maintenance)
 - Vulnerability introduced by dependency on GNSS technologies
- **Financial considerations**
 - Training of staff, new equipment acquisition and conversion of legacy data
- **Legal implications**
 - Liability situations resulting from inadvertent errors
 - Possible requirement to review and amend wording of legal documents

User Impacts



Short Term:

- Benchmarks will have published heights in both CGVD28 and new vertical reference system
- CGVD28 and new datum will both be accessible by spirit levelling technique (BMs still available)
- The new vertical datum will be directly accessible by space-based technologies
- The new vertical datum will be more accurate over longer baselines and offer uniform coverage across Canada
- **CGVD28 will continue to co-exist with new vertical datum**

User Impacts



Long Term:

- Access to CGVD28 will become more difficult as benchmarks disappear or deteriorate (become unstable)
- The vertical datum will be accessed mainly through space-based technologies (GNSS, radar altimetry, ...)
- Local and regional surveys will still be performed with spirit levelling but the use of GNSS technology may be required to access the reference and provide quality control
- Maintenance of a sparse infrastructure of monumented high-precision 3D control will be required to support differential GNSS processing and monitor the reference frame stability (combination of coherent federal CBNs and *provincial HPNs*)

Proposed Implementation Schedule



	06/07	07/08	08/09	09/10	2010 +
Height Modernization consultation	→				
Confirm implementation plan and Communication Strategy	→				
Data collections & analysis (GPS/levelling/gravity & DEM)	*	→			
Stakeholder communications / Education / Support		→	→	→	→
Development of tools using preliminary geoid models		→	→	→	
Computation of <u>new geoid model</u> including GOCE data			→		
Adoption and publication of a new geoid model				→	
Publication of new heights for classical levelling network				→	
Transition period (CGVD28 / New datum)				→	→
Infrastructure maintenance (ACS, CBN, and HPN)					→
Geoid model maintenance					→

*** Launch of the GOCE satellite gravity mission (1-2 cm accuracy at a spatial resolution < 400 km) delayed to early 2008.**

Conclusion



- In terms of accuracy and accessibility, CGVD28 does not satisfy today's user needs for precise height determination.
- The most viable alternative for the realization of a lasting and sustainable vertical datum in Canada, compatible with GNSS technologies and international standards, is a geoid model.
- The new datum will change the heights assigned to benchmarks within a range of one metre across Canada. However, local height differences will maintain the same relative precision of a few mm.
- NRCan, in cooperation with provincial and territorial geodetic agencies, is moving ahead with the implementation of a modernized height reference system.
- Stakeholder interaction, tools development, education and data dissemination will be essential components of this initiative.