



INTRODUCTION

The aim of this study is to test the geoid solutions in Canada obtained with the recently released GOCE models, by assessing them in the Great Lakes and Rocky Mountains regions. A GOCE&GRACE only model, GOCO01S, is combined with local terrestrial data. Remove-compute-restore technique is used to combine the satellite and terrestrial data in Helmert's space.

GPS/Leveling-derived geoid undulations are used as control values in the evaluation of the satellite-only and combined geoid models. In addition, the EGM2008 global geopotential model and the previous Canadian geoid model CGG2005 are included in the comparisons.

Any improvements from GOCE solutions are important since the new Canadian geoid model will be used as the vertical datum in Canada by 2013. The expectation is the development of a cm accurate model and the new generation of GOCE models will be a main contributor.

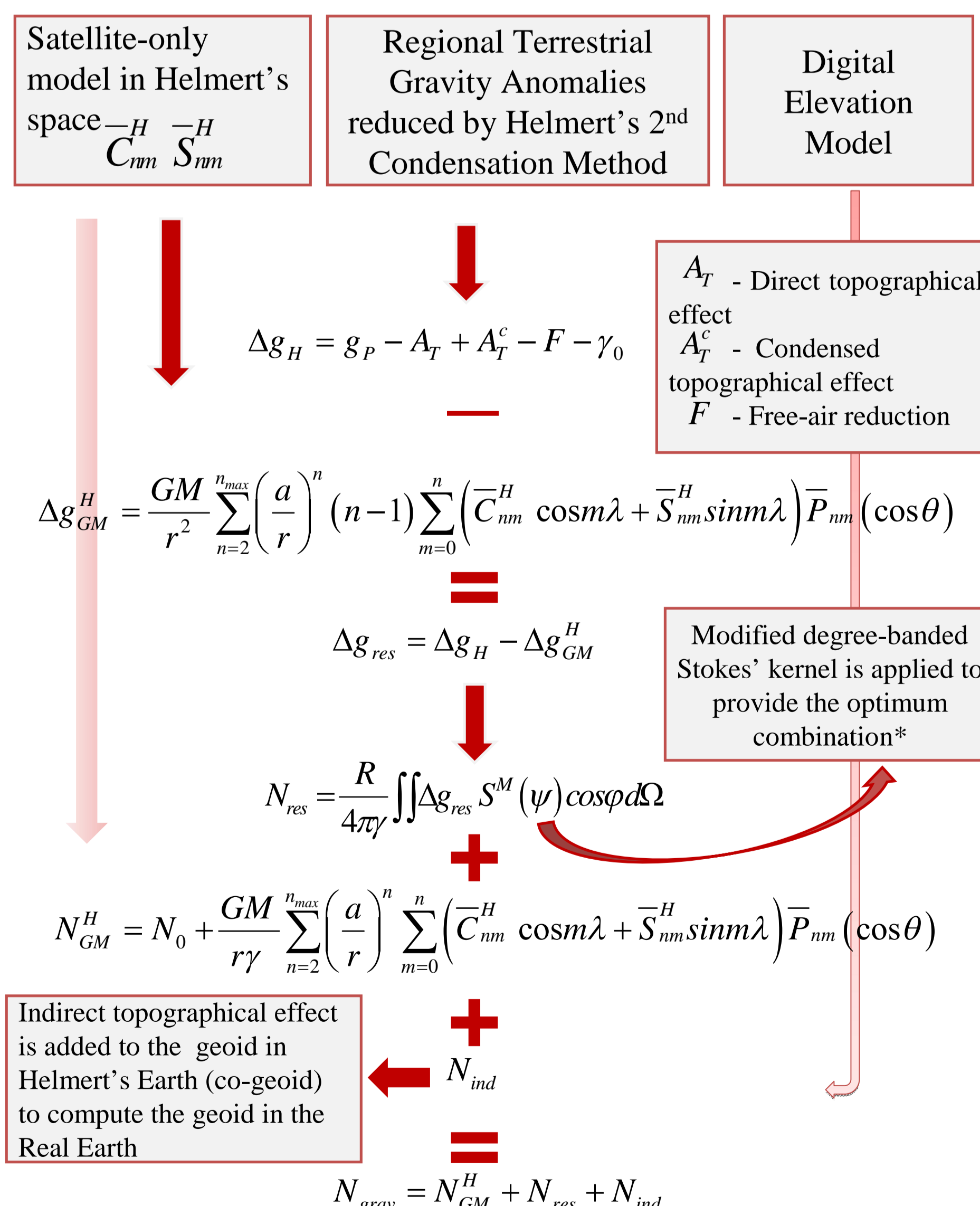
DATA

- GOCE-only and GRACE&GOCE based satellite-only global gravity field models: First generation GOCE solutions, DS01, TW01, SW01, and GOCO01S, obtained from the first two-month observation cycle,
- Regional 2' x 2' gridded Helmert gravity anomalies and
- Digital Elevation Model in 2 minute grid interval obtained from the Geodetic Survey Division of Canada.

METHODOLOGY

Geoid Computation (Remove-Compute-Restore Technique)

- Helmert-Stokes Scheme is followed to reduce the gravity anomalies to the geoid and to obtain geoid heights from the gravity anomalies.
- Remove- compute- restore technique is applied in combining a global gravity field model, surface gravity anomalies, and digital elevation data.
- Global gravity field model included in the combined model is also Helmertized by modifying the coefficients from the gravity potential differences of the Real Earth, W and the Helmert's Earth, W_H which is called as residual topographical potential.



*Huang, J. and Véronneau, M. (2011): Using the satellite gravity model to improve the geoid in Northwestern Canada and Alaska, *Journal of Geodesy manuscript* No., in preparation

RESULTS 1

- Geoid undulations obtained by the three first generation GOCE-only models (DS01, TW01 and SW01) and one GRACE&GOCE combined (GOCO01S) satellite-only solution are investigated in Canada by comparing them with GPS/Leveling derived geoid undulations on 2579 benchmarks in absolute $H = h_{GPS} - N_{grav}^H$ and relative sense $\Delta N_{i,j}^{GPS} - \Delta N_{i,j}^{grav} = (h_{GPS,j} - H_j - h_{GPS,i} + H_i) - (N_{grav,j} - N_{grav,i})$.
- Two sub-regions marked by red rectangles in Figure 1 are included to observe GOCE model performance locally and possible improvements in the regional geoid models from GOCE.

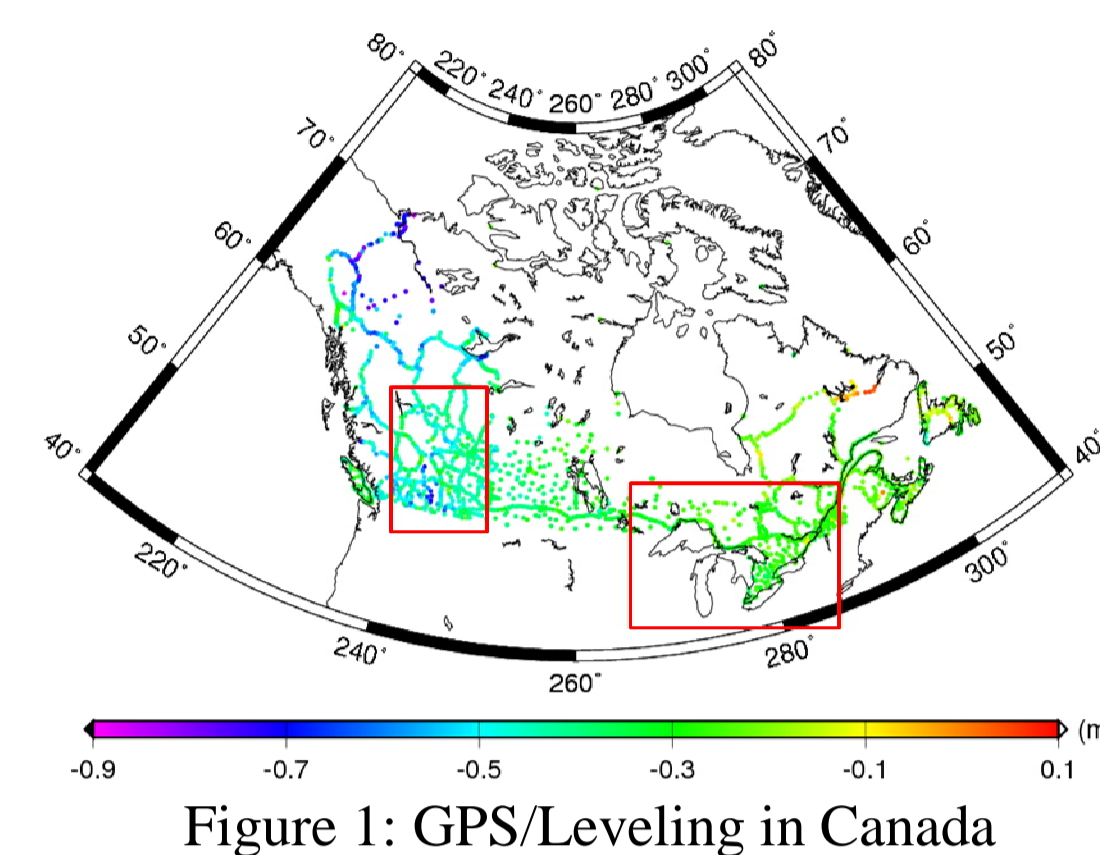


Figure 1: GPS/Leveling in Canada

•Figure 1 displays the distribution of the GPS/Leveling benchmarks in Canada and the differences between the geoid undulations derived from GPS/Leveling and EGM2008 up to spherical harmonic degree 2190 in meters with the colour range from -0.9 m to 0.1 m.

•The satellite-only geoid models expanded up to a certain spherical harmonic degree, n_{max} are compared with the GPS/Leveling derived geoid heights where the omission error (above degree n_{max}) predicted from EGM2008 is removed. This step makes two independent solutions consistent in terms of spectral resolution and Figures 2 a,b,c display the absolute agreement results. Figures 3 a b c display the relative results.

Absolute and relative agreement of the GOCE solutions with GPS/Leveling derived geoid undulations

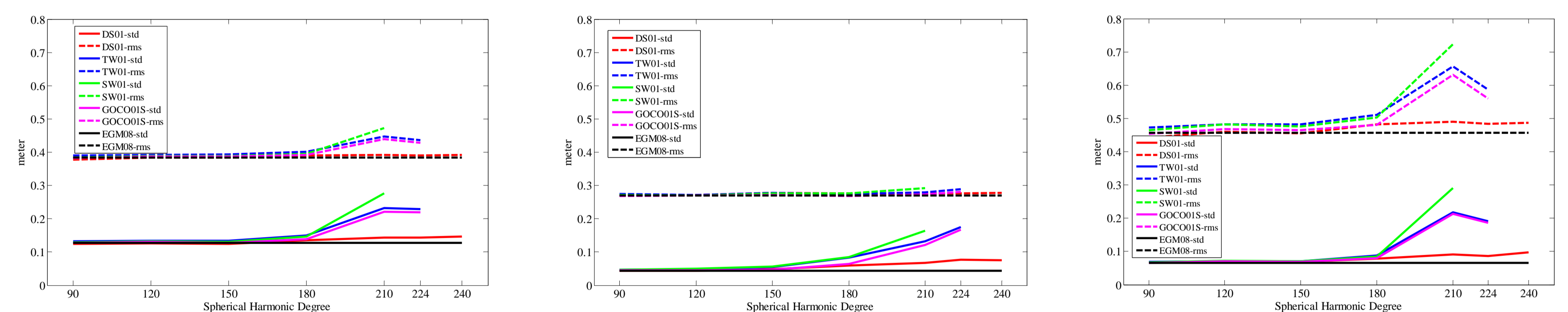


Figure 2 a,b,c: Standard deviations (std, solid) and root mean squares (rms, dashed) of $h_{GPS} - H - N_{grav}$ in meters as function of the spherical harmonic degree of the three first generation GOCE-only solutions (DS01, TW01, SW01), the combined GRACE-GOCE model GOCO01S and EGM2008 in Canada, GL and Rockies on 2579, 652 and 658 benchmarks, respectively.

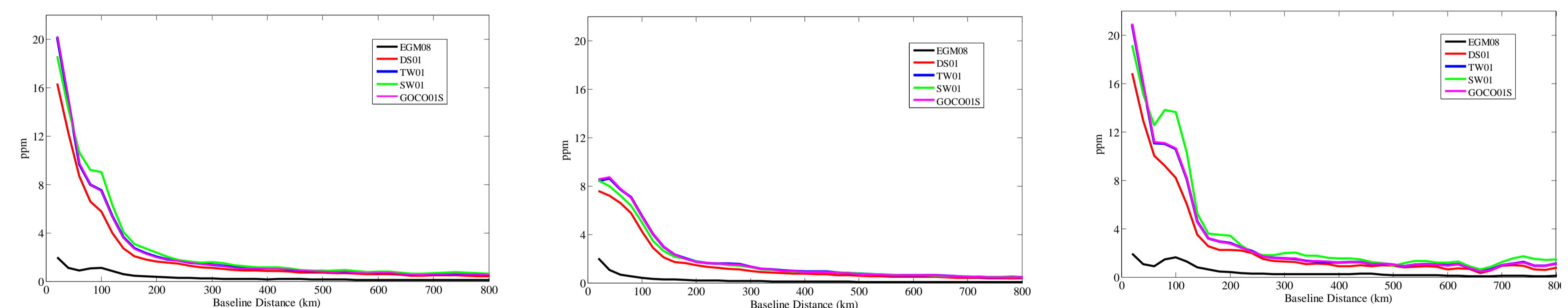


Figure 3 a,b,c: Relative undulation accuracy [ppm] as function of baseline distance [km] for Canada, the GL, and Rockies from EGM2008, three first generation GOCE solutions (DS01, TW01, and SW01) and the GRACE-GOCE model GOCO01S.

RESULTS 2

- GRACE&GOCE combined satellite-only model: GOCO01S is combined with regional terrestrial gravity data.
- Different spherical harmonic degree combined models are tested to determine the optimum combination of the satellite model and terrestrial data.
- When the combined model is determined, a satellite model is not truncated. Instead the combination is done through the kernel modification at a specific degree.
- The satellite model is used up to its maximum degree to account for the far-zone contribution.

Table 1: Statistics of the combined models, standard deviations before and after 4-parameter corrector surface fitting (in parenthesis) of the misclosures are given in meters.

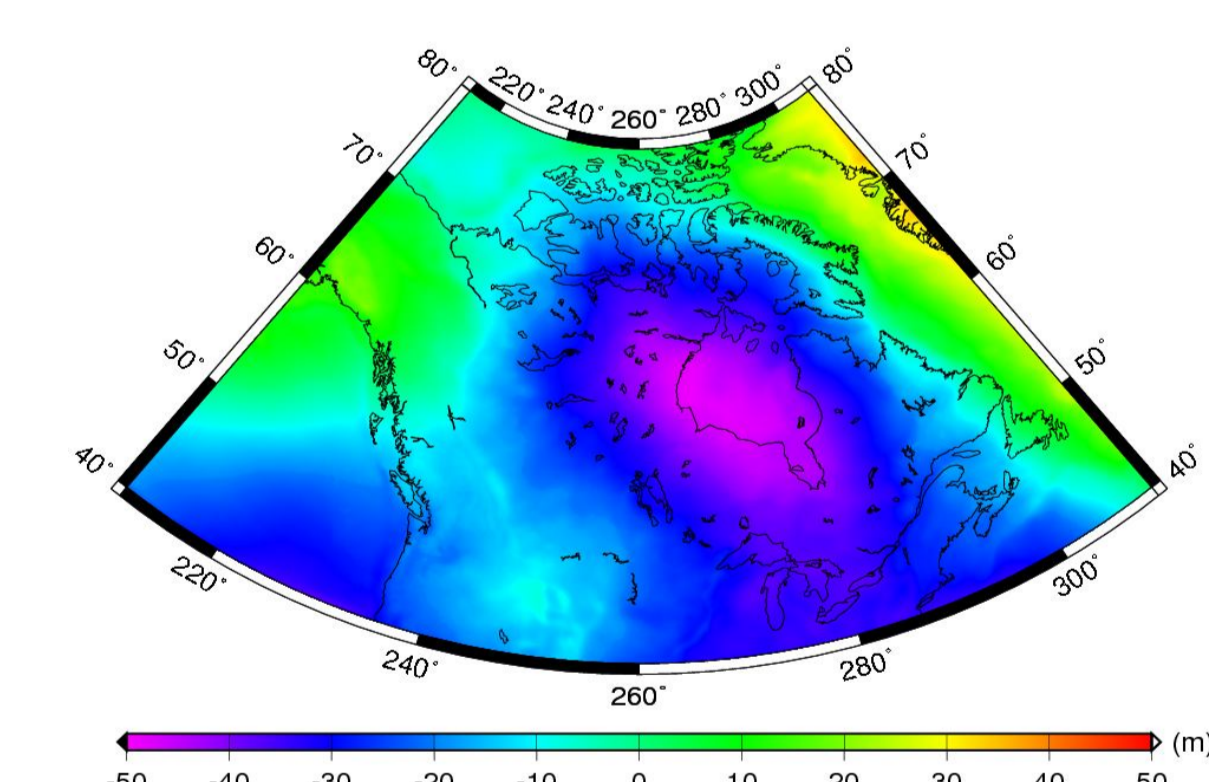


Figure 4: Geoid model obtained from the GRACE&GOCE model and regional terrestrial gravity data.

- GOCE model updates the medium frequency information of the gravity field in Canada.

Models\Region	Canada	GL	Rockies
EGM2008	0.127 (0.079)	0.044 (0.039)	0.066 (0.063)
CGG2005	0.132 (0.086)	0.055 (0.050)	0.071 (0.064)
GOCO_120_Terrestrial	0.119 (0.082)	0.050 (0.047)	0.068 (0.065)
GOCO_150_Terrestrial	0.124 (0.078)	0.044 (0.041)	0.073 (0.065)
GOCO_170_Terrestrial	0.124 (0.078)	0.045 (0.043)	0.074 (0.065)
GOCO_200_Terrestrial	0.126 (0.082)	0.054 (0.051)	0.078 (0.069)

CONCLUSIONS

- According to the comparisons made in absolute sense, it is shown that the GOCE-only models show a good agreement with EGM2008 for the lower degrees up to 150-180 in Canada. GOCE model components above spherical harmonic degree 180 should not be included in the combined geoid model for Canada (see Figures 2 and 3).
- The combined models with the GRACE&GOCE satellite-only solution and regional terrestrial gravity data provide best results. Nationally, the absolute agreement (st. dev.) with the GPS/Leveling derived geoid undulation is 11.9 cm on 2579 benchmarks. It becomes 4.4 cm for the Great Lakes area and 6.8 cm for the Rockies. These results are comparable with the testing results of EGM2008 and CGG2005 considering errors in the GPS/leveling data (see Table 1).
- Based on our results, there is not enough evidence so far to indicate that the first generation GOCE models (obtained from a two-month observation cycle) provide significant improvement of the geoid model in Canada. The upcoming GOCE-only and GRACE&GOCE models with a longer time series should provide even more accurate solutions.

ACKNOWLEDGEMENTS

Geodetic Survey Division, Canada Center for Remote Sensing, Natural Resources Canada,

GEOIDE NCE, NSERC