Canada 1 Water: Towards integrated gravity – water storage change models for regional and national scale monitoring

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Large scale changes in water storage produce changes in gravity that can be measured and used for monitoring. However, the cause-and-effect relationship is not unidirectional. Large changes in gravity also impact hydrology, water flow, and water surface topography. The new vertical datum (mean sea level) for North America, the North American Pacific Geopotential Datum (NAPGD2022), will for the first time contain a time dependent component. While much of the large-scale temporal changes are driven by tectonic processes such as glacial isostatic rebound, changes in water and ice are significant contributors as well. Details on water storage changes through time are often required to explain the complex non-linear gravity signals observed and to produce meaningful gravity (or vertical datum) change models. As such, studying changes in gravity and water storage in parallel helps us refine our approaches and improve our estimates of both. A good example of this is the Canada1Water (C1W) project which aims to develop a national scale coupled surface water - groundwater model to provide decision support tools to inform on surface water - groundwater quantity and related impacts such as droughts, floods, carbon sequestration availability, wildfire risk, permafrost changes, and ecosystem service value. Satellite gravity observations from the GRACE and GRACE-FO missions are helping to provide important large scale water balance constraints for basins within the C1W project. These constraints are critical for validating and calibrating the surface and subsurface flow domains within the C1W fully-integrated groundwater – surface water models. Once hydrological models have been validated at a large scale, they can then be used to help interpret gravity change signals at a much finer resolution than is currently possible with satellite gravity.

We will discuss a case study for southern Ontario that demonstrates our ability to accurately capture changes in regional water storage using satellite gravity data. We focus on southern Ontario as there are abundant hydrological observations and sophisticated models, such as the regional scale HydroGeoSphere model, that can be used to validate the GRACE estimates. We show that GRACE/GRACE-FO effectively captures and quantifies both extreme events and regular seasonal behavior. Furthermore, the GRACE results demonstrate that the large and recent changes in the Great Lakes water levels have little correlation with seasonal changes in total water storage for southern Ontario, which have remained relatively consistent over the same period. We conclude with a brief discussion of how our method is being applied at the national scale to identify areas of interest and to further help with C1W model validation and calibration.

Keywords: GRACE, satellite gravity, hydrology, climate change

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