High-Resolution Temporal Geoid Modeling in Alaska for a New Geopotential Datum

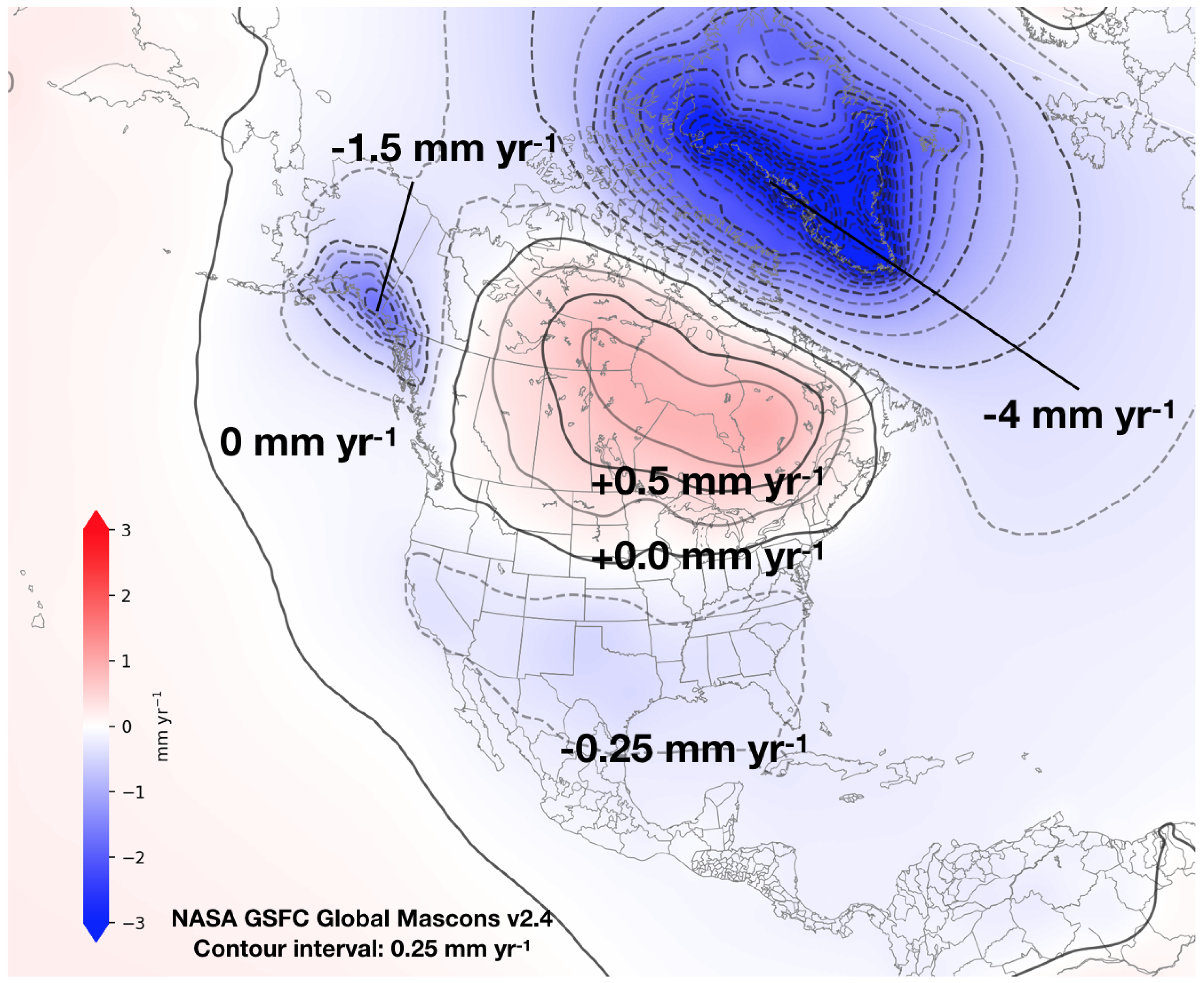
Ryan A. Hardy[1], Kevin M. Ahlgren[2], Bryant D. Loomis[3], Xiaopeng Li[2],
[1]NRC Research Associateship Program, [2]NOAA National Geodetic Survey, [3]NASA Goddard Space Flight Center
ryan.hardy@noaa.gov | 2019 AGU Fall Meeting, San Francisco | G53C-0637

Summary

The US National Geodetic Survey will introduce a geoid model to serve as the basis for a new geopotential datum in 2022. Because the geoid changes in time, this model must account for geoid change signals of more than 1 cm on decadal timescales to maintain its accuracy. The GRACE mission provided monthly geopotential solutions that may be converted to geoid trends at ∼300 km resolution, which is adequate for capturing most geopotential change in North America. However, highly localized ice mass loss from mountain glaciers in Alaska produces geoid change signals exceeding 2 mm yr^{-1} at higher spatial resolution than GRACE can capture.

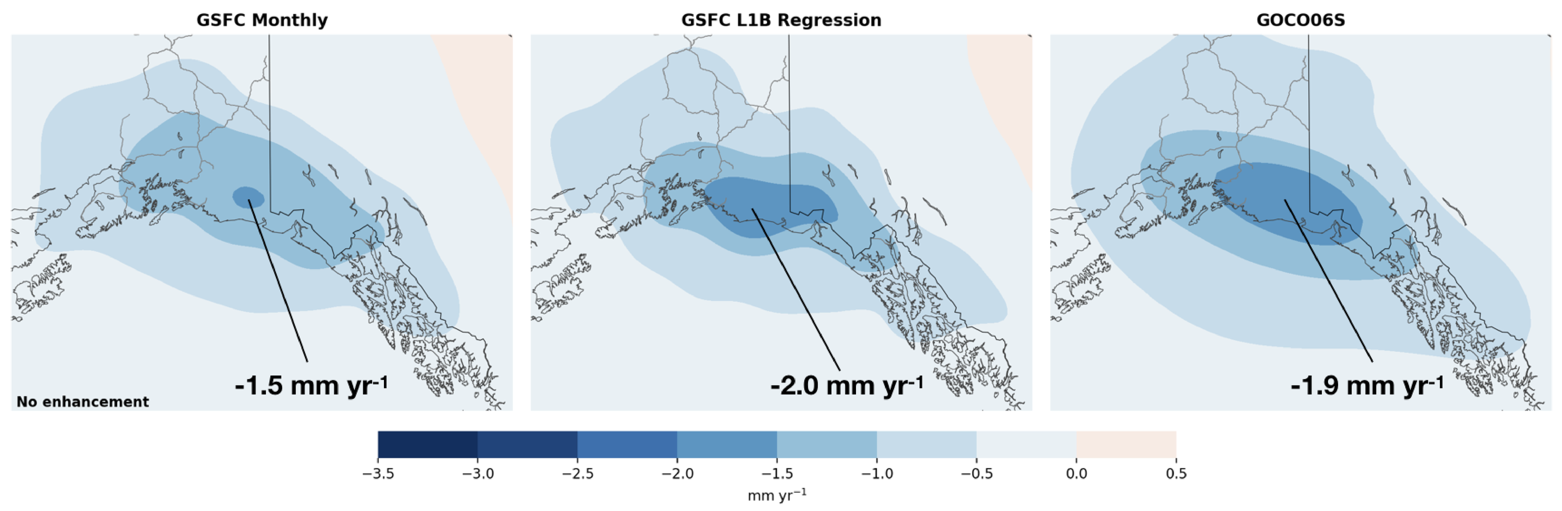
To predict present-day geoid change at high spatial resolution, we combine Goddard Space Flight Center mascon solutions with high-resolution ice mass loss rates developed with data from ICESat, ICESat-2, and airborne lidar missions to generate high-resolution predictions of geoid change. We also use comparisons of modern altimetry with aerial photogrammetry from the mid-20th century to develop compatible models of past geoid change. The combination of past and present-day geoid change models generates predictions that may be tested by revisiting historical geodetic observation profiles in Alaska with GNSS and terrestrial gravity.

2002–2016 Geoid Rate



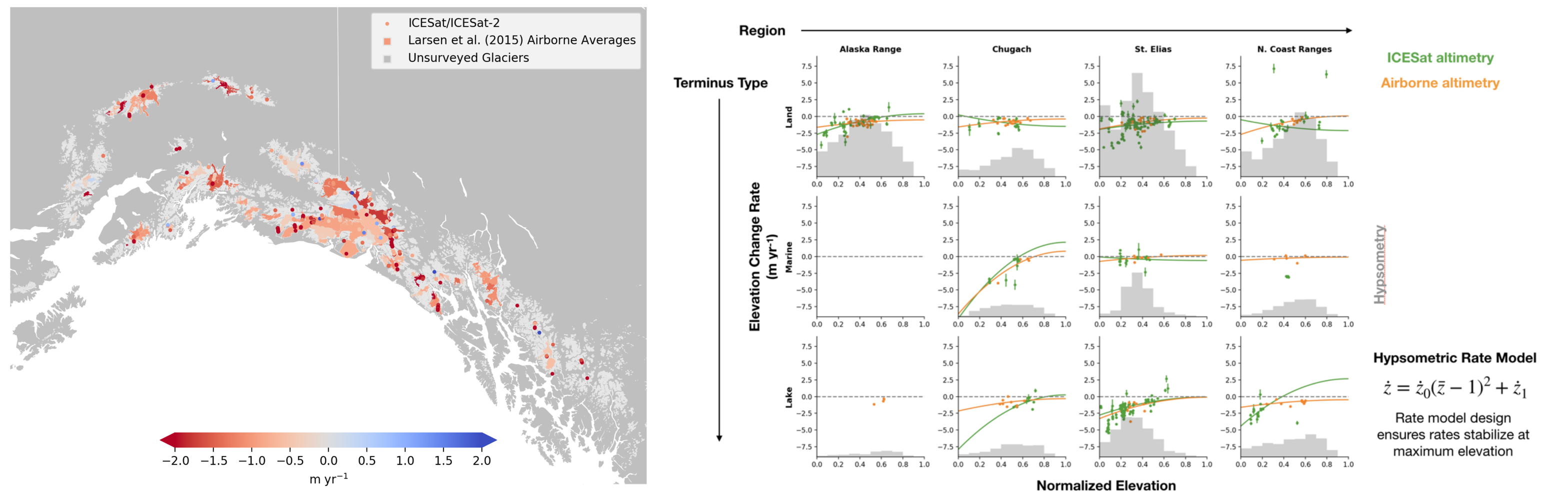
High-Resolution GRACE Solutions

GRACE solutions may be enhanced by trading temporal resolution for spatial resolution, estimating geopotential trends instead of monthly solutions. Two high-resolution GRACE trend solutions, Goddard L1B Regression Mascons and GOCO06S, provide direct evidence of truncation of at least 0.5 mm yr^{-1}.

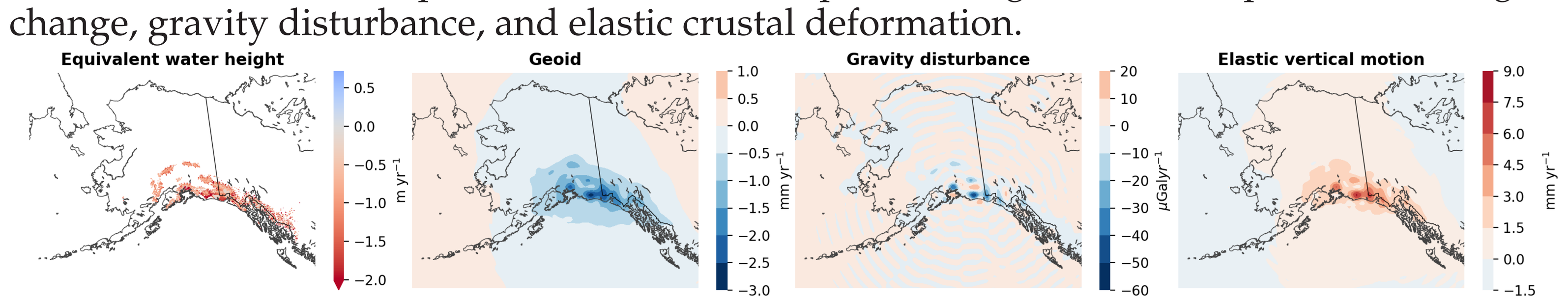


Geoid Change Rates from GRACE & Altimetry

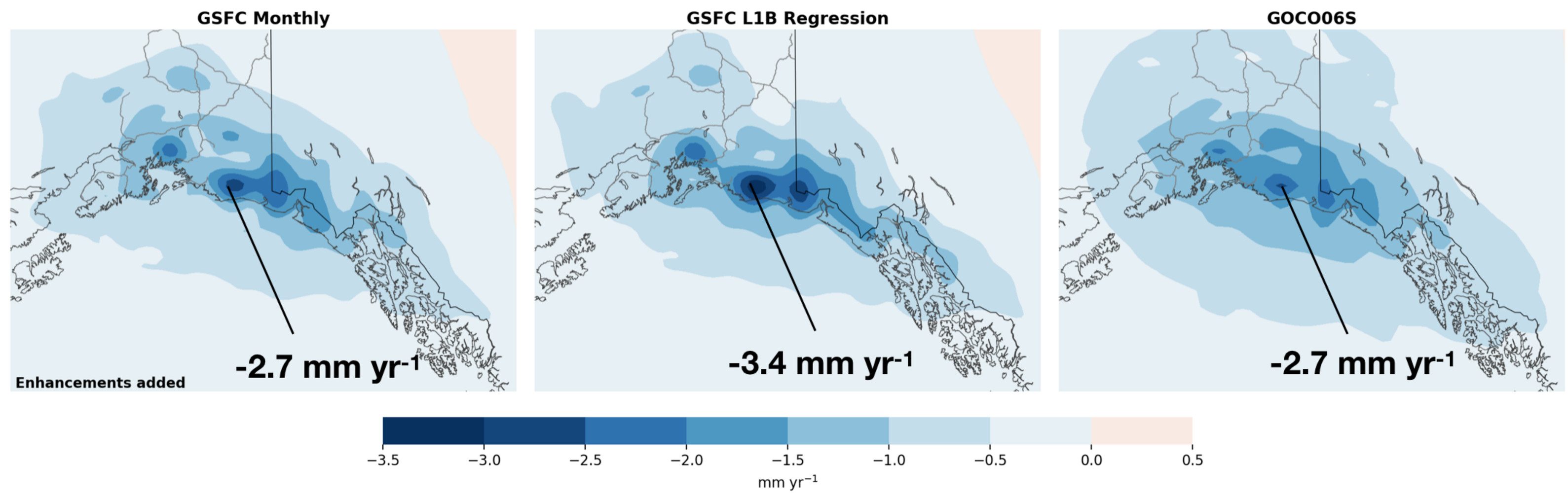
Airborne (Larsen et al., 2015) and satellite altimetry from ICESat and ICESat-2 provide multi-decade, high-resolution samples of glacier elevation change. These elevation change rates may be predicted by models parameterized by glacier type and normalized hypsometry, enabling extrapolated grids of mass change rates in across Alaska's glaciated area.



These high-resolution mass change models are combined with low-resolution GRACE trends in a remove-compute-restore scheme to produce high-resolution predictions of geoid change, gravity disturbance, and elastic crustal deformation.



The enhanced geoid change models at d/o 360 reveal multiple distinct load centers unresolved by GRACE solutions alone.

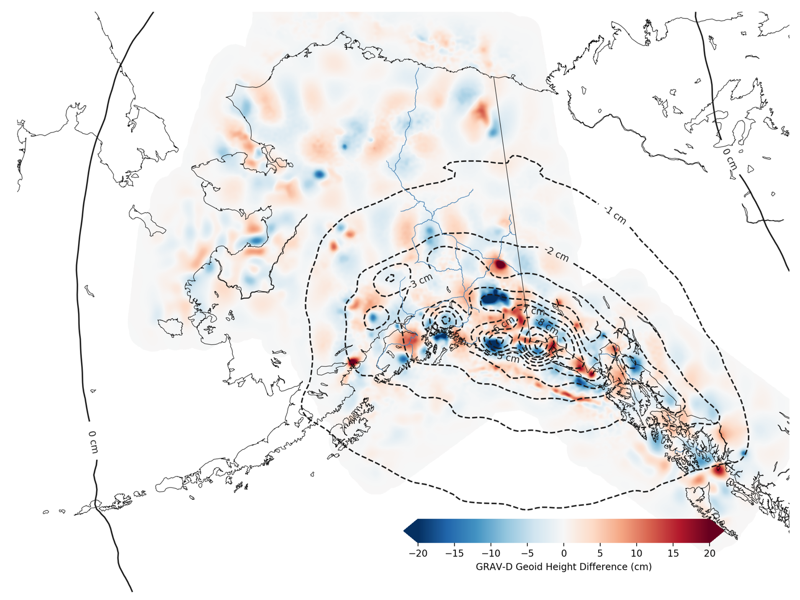


Past Geoid Change

Airborne lidar (ca. 1996) data compared with photogrammetric contours (ca. 1954) released by Echelmeyer et al. (2002) provide direct evidence of ice surface elevation change of up to ∼300 m in Alaska. These ice elevation changes may be parameterized by normalized elevation and glacier classification and extrapolated across the glaciated area of Alaska to predict the elastic, ice-mass driven component of geoid change in Alaska from 1954–1996. This approach predicts up to 8 cm of geoid change, hundreds of μGal of gravity disturbance change, and several dm of uplift.

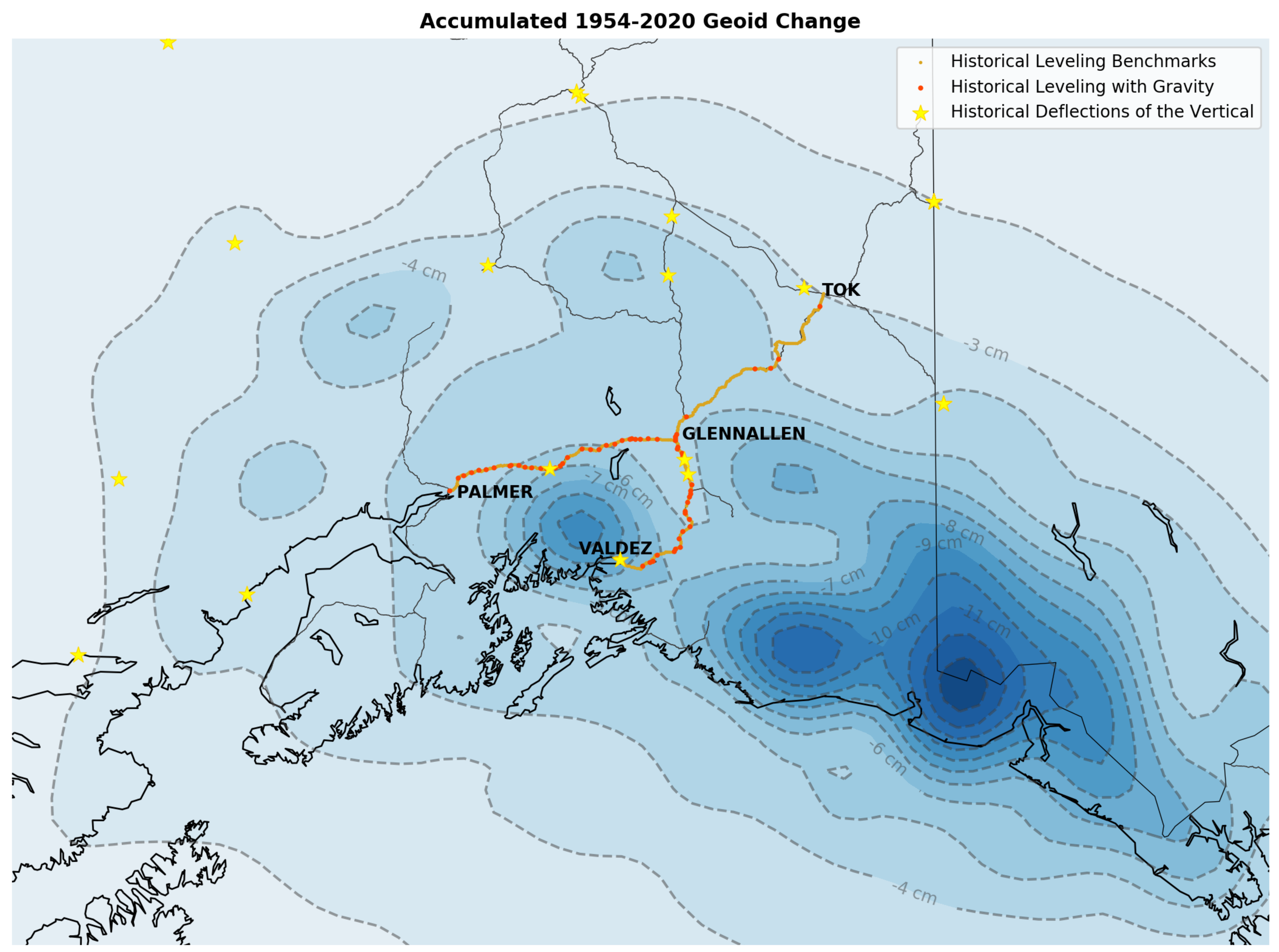
Additional evidence of past geoid change comes from comparison of static geoid models derived from airborne gravimetry collected in 2010 with geoid models derived from terrestrial gravity collected ca. 1950–1990. Because satellite models with a reference epoch of 2010 constrain the low-degree components of the geoid, the difference between the airborne and terrestrial-only models should reveal temporal aliasing aligned with the predictions for geoid change at high spatial frequency.

Below: The difference between NGS's xGEOID19B (terrestrial, airborne, satellite) and xGEOID19A (terrestrial and satellite only) compared with contours of predicted geoid change across 1954–2010.

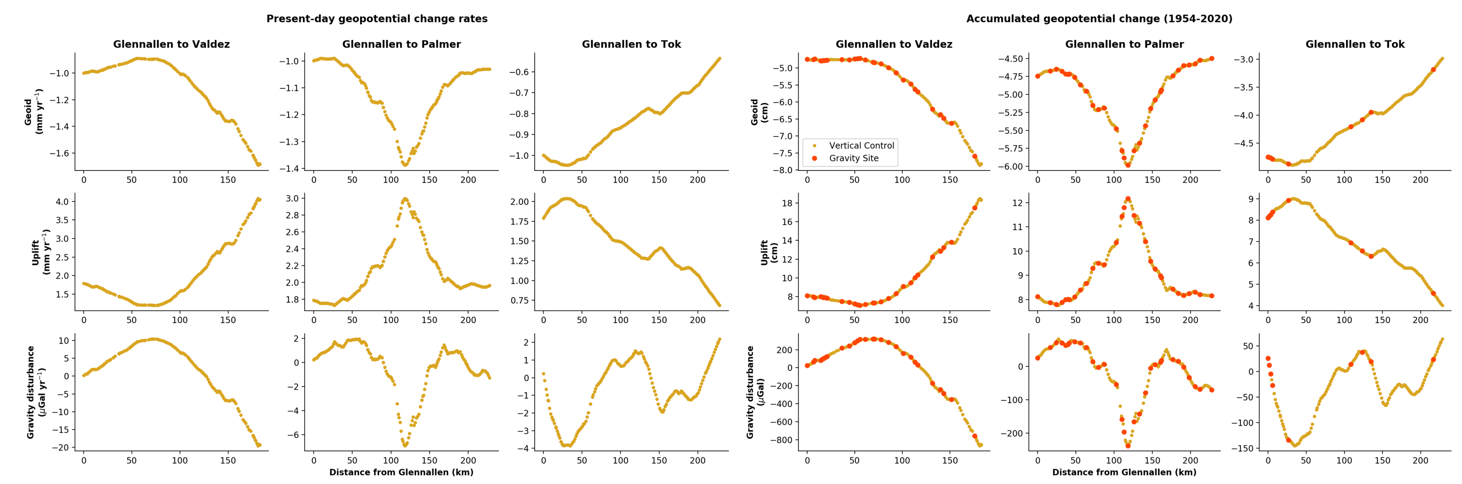


Planned Observational Validation

These models may be validated directly using simultaneous repeat GNSS and terrestrial gravity profiles with ∼20 km spacing as part of NGS's Geoid Monitoring Service. These surveys will isolate individual centers of ice mass loss and geopotential change at unprecedented spatial resolution. Such surveys can also capture half a century of geoid change at the locations of simultaneous leveling and terrestrial gravity campaigns following the 1964 Alaska earthquake. Repeats of mid-20th century deflection-of-the-vertical observations can also constrain geoid change.



The planned survey profiles are expected to capture multiple cm of differential geoid and elevation change and hundreds of μGal of gravity disturbance change. Repeats of these surveys should also capture differential geoid rates of up to 1 mm yr^{-1} across the profiles in addition to several μGal yr^{-1} of gravity change and several cm yr^{-1} of elastic uplift.



Conclusions & Future Work

This work demonstrates that geoid change in Alaska can exceed 2 mm yr^{-1} and that GRACE solutions can truncate at least 0.8 mm yr^{-1}. Maintaining a 1 cm geoid accuracy therefore requires combination of GRACE with altimetry-driven ice mass models. These models, when combined with models driven by historical ice elevation change data predict geoid changes of more than 10 cm over the past 60 years, which will be verified by forthcoming terrestrial gravity and GNSS validation surveys.

These models assume that non-ice components of geoid change are captured by GRACE. Integration of forward geophysical GIA, tectonic, and seismic models will improve the fidelity of these predictions. A necessary step of this analysis will be uncertainty quantification.

This research was performed while the first author held an NRC Research Associateship award at NOAA's National Geodetic Survey.

Go Deeper: NOAA Technical Report NOS NGS 69: A Preliminary Investigation of the NGS's Geoid Monitoring Service (GeMS)