Impact of local crustal variations and ice mass balance uncertainties on interpreting regional GIA in southeast Alaska

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Motivation

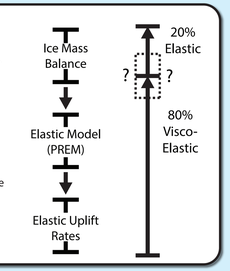
Long Term Goal:
- Separate elastic deformation from present-day deglaciation and viscoelastic response

This Poster:
- Update previous estimates of ice mass balance and uncertainties
- Quantify elastic uplift rate uncertainties that result from choice of elastic structure, anelasticity, and the propagation of ice mass balance uncertainties
- Model elastic uplift rates

1) Can the Shuttle Radar Topography Mission (SRTM) correctly be used for estimating ice thinning rates?

2) How sensitive are our estimates of ice mass loss to seasonal variability?

3) How do elastic uplift rates modeled from local elastic structures differ from those modeled from PREM?



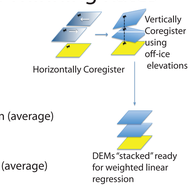
Methods 1: Ice Thinning Rates

Calculate dh/dt using DEM time series

SRTM:
Feb. 2000

ASTER:
Jul. 2000 - May 2017
15 dates at each location (average)

ArcticDEM:
Oct. 2008 - Sep. 2016
2 dates at each location (average)



Uncertainties

Previous studies[6]
- DEM Errors
- Cloud Coverage
- Glacier Density

This study
- ***SRTM Penetration Depth***
- ***Seasonal Aliasing***

Results 1: Can the SRTM correctly be used to estimate dh/dt?

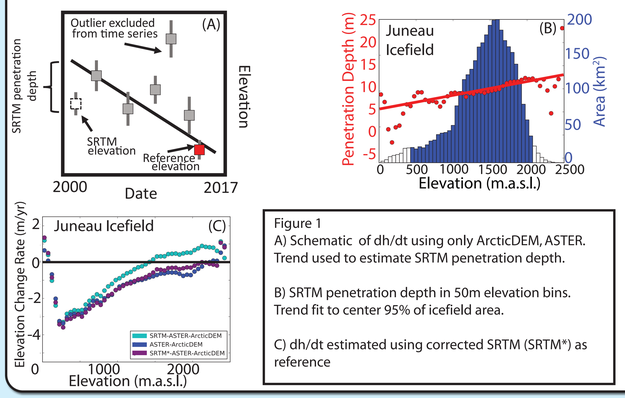


Figure 1
A) Schematic of dh/dt using only ArcticDEM, ASTER. Trend used to estimate SRTM penetration depth.

B) SRTM penetration depth in 50m elevation bins. Trend fit to center 95% of icefield area.

C) dh/dt estimated using corrected SRTM (SRTM*) as reference

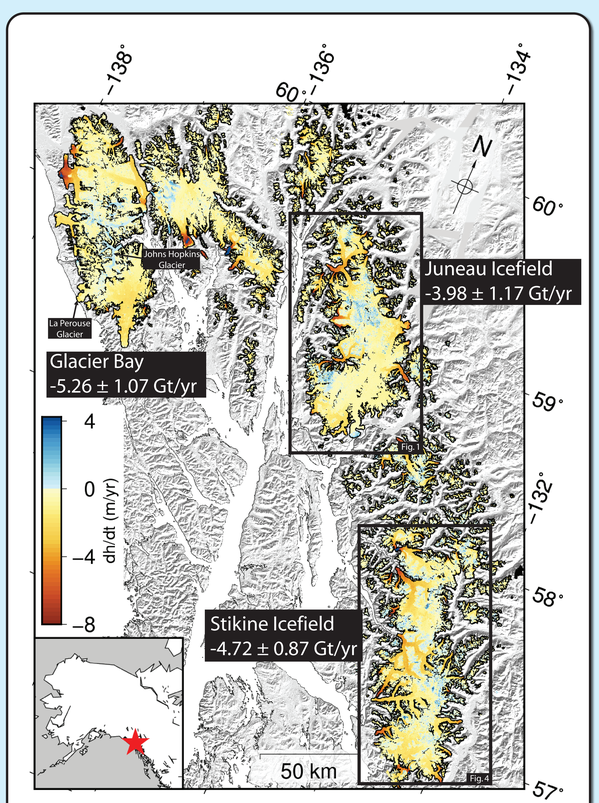
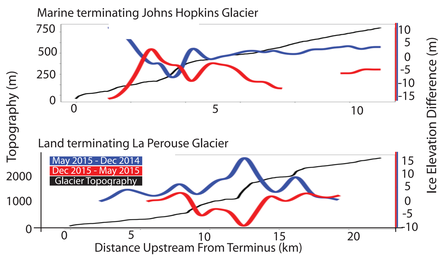


Figure 2

Ice thinning rates estimated from corrected SRTM (Figure 1), ASTER, and ArcticDEM elevation time series spanning 2000-2017

Results 2: Do seasonal changes impact decadal estimates?

Quantified Seasonal Variability



Theoretical Seasonal Impact on Decadal dh/dt

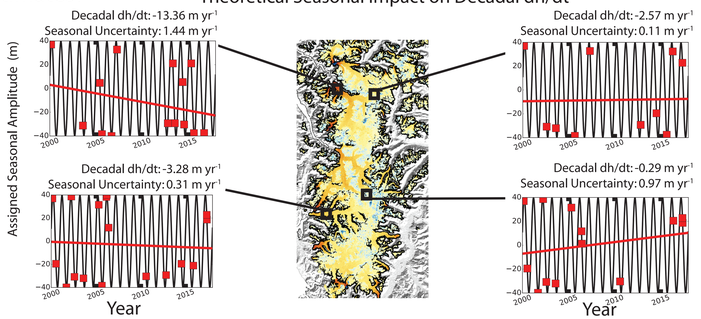


Figure 3
Quantify seasonal variability in different regions with ArcticDEM

Difference DEMs to measure accumulation (blue) and ablation (red)

Seasonal variations unknown for most glaciers, but can be ~15 m

Figure 4
Impact of seasonal variability on decadal trend using sine wave with large amplitude (40m)

Uncertainty as magnitude of slope of line fit to DEM dates on sine wave

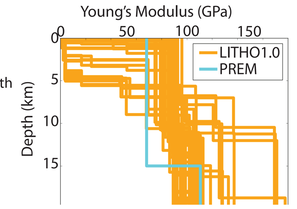
When all sources of uncertainty are added in quadrature,
seasonal uncertainties constitute 0.3% of total mass loss uncertainty

Methods 2: Elastic Deformation using a suite of plausible models

Most studies model elastic deformation with PREM[1,2,4]

Southeast Alaska is tectonically complex
May not be well represented by PREM
May not be well represented 1D model

Seismically derived elastic models not sensitive to anelastic interactions with pores, microfractures



Elastic Deformation Workflow

Love numbers calculated using open-source GIAPY[5] with 42 LITHO1.0[7] profiles

Anelasticity estimated with empirical relation[8]

Elastic Deformation on 1D, spherical Earth estimated using Regional ElAstic Rebound calculator (REAR)[5]

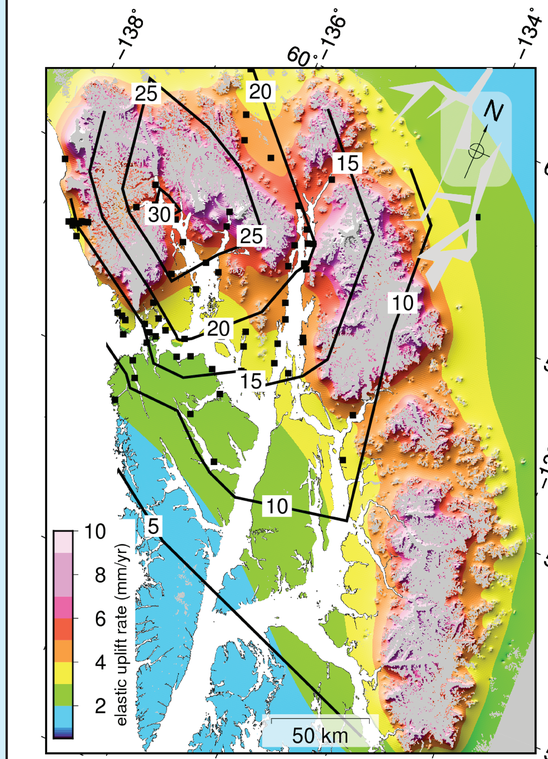


Figure 6
Elastic uplift rates estimated using PREM elastic structure

Differences from those estimated using LITHO1.0 not visible at this scale

GPS observations of total uplift contoured in black[2]

Elastic uplift rates up to 20-30% of peak total uplift

Results 3: How do elastic uplift rates modeled from local elastic structures differ from those modeled from PREM?

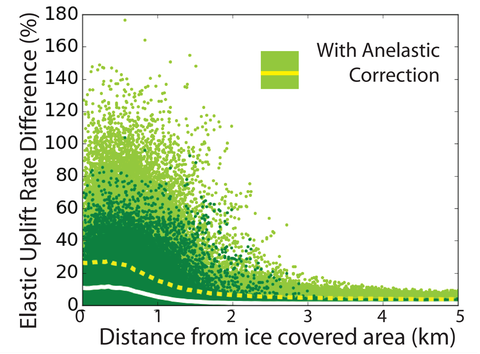


Figure 7
Solid and dashed lines show 50m moving average.
Close to ice, difference can be large enough to impact glaciological studies

Results 4: Do elastic uplift rate uncertainties impact interpretations of GIA deformation?

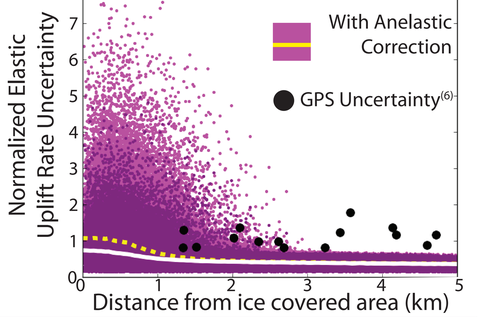


Figure 8
Solid and dashed lines show 50m moving average.
Distances >2.5km from ice (majority of GPS) elastic uplift rate uncertainty predominantly from propagation of ice mass balance uncertainty
Does not significantly impact GIA interpretations

Conclusions

1) Ice thinning rates based on corrected SRTM reference and ASTER/ArcticDEM reference in agreement. Extends dh/dt coverage to cloudy regions where optical data are sparse.

2)Seasonal variability in snow/ice elevation (even 40 m) does not appreciably affect multi-decadal time series from ASTER, ArcticDEM and SRTM with dates randomly collected throughout all seasons.

3) Elastic uplift rates modeled using local elastic uplift structures up to 60-100% larger than those modeled from PREM within 2.5 km distance from ice. Important implications for studies that constrain ice mass balance or glacier density using elastic deformation observations

4) Beyond 2.5 km distance from ice covered areas (where most GPS are located), propagation of ice mass balance uncertainties dominate and do not significantly impact GIA interpretations

References

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(3) Kachuck, Samuel B. (2017) giapy: Glacial Isostatic Adjustment in PYthon (1.0.0) [Source code] https://github.com/skachuck/giapy.
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(6) Melkonian, Andrew K., Michael J. Willis, and Matthew E. Pritchard. "Satellite-derived volume loss rates and glacier speeds for the Juneau Icefield, southeast Alaska." Annals of Glaciology 55.66 (2014): 75-84.
(7) Pavlis, Nikolaos K., et al. "The development and evaluation of the Earth Gravitational Model 2008 (EGM2008)." Journal of geophysical research: solid earth 117.B4 (2012).
(8) Yale, D. P., and V. Swami. "Conversion of Dynamic Mechanical Property Calculations to Static Values for Geomechanical Modeling." 51st US Rock Mechanics/Geomechanics Symposium. American Rock Mechanics Association, 2017.