Jet Propulsion Laboratory
California Institute of Technology

Amplified seasonal waves of glacial mass transport detected in Greenland crustal motions

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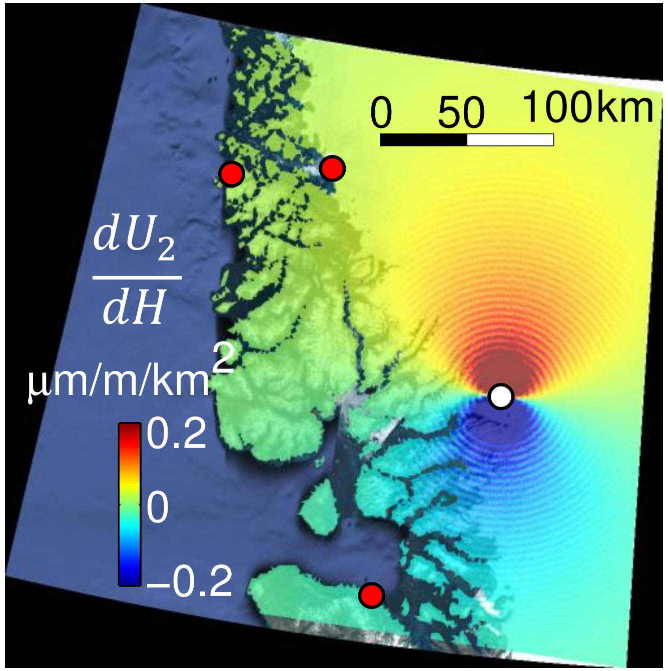
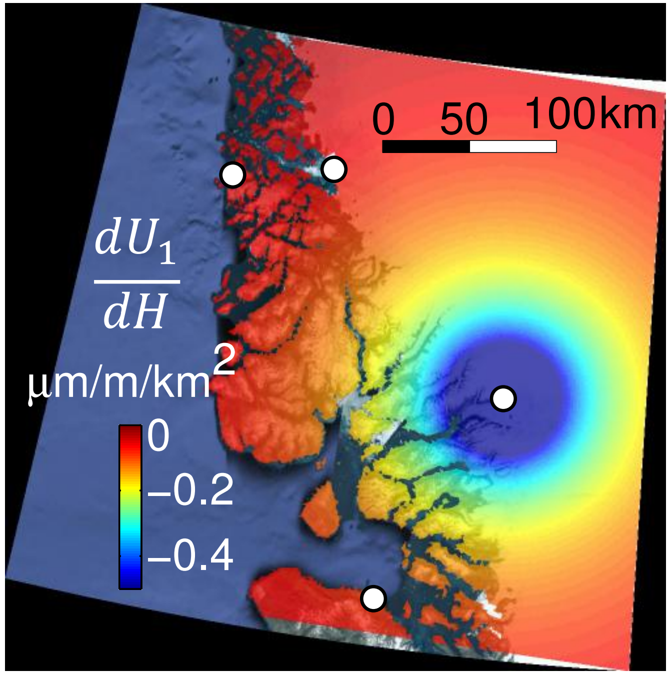
Rink Glacier (April 9, 2010)
Credit: Operation IceBridge

1. Observational/theoretical background

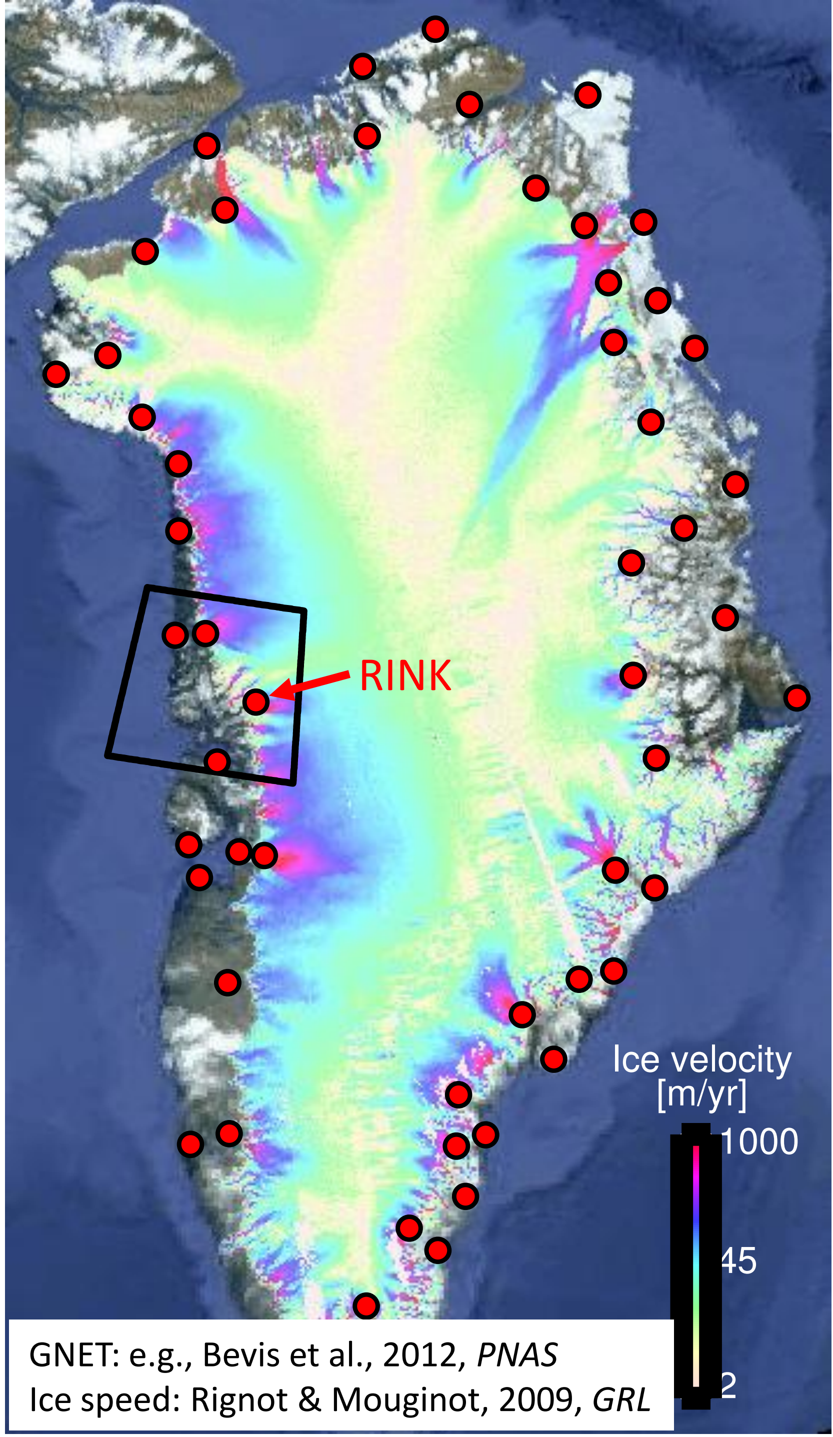
All 3 components of $\vec{U}$ are not fully exploited

- Horizontal displacements are much smaller than vertical,
- and, these are relatively difficult to interpret(!)

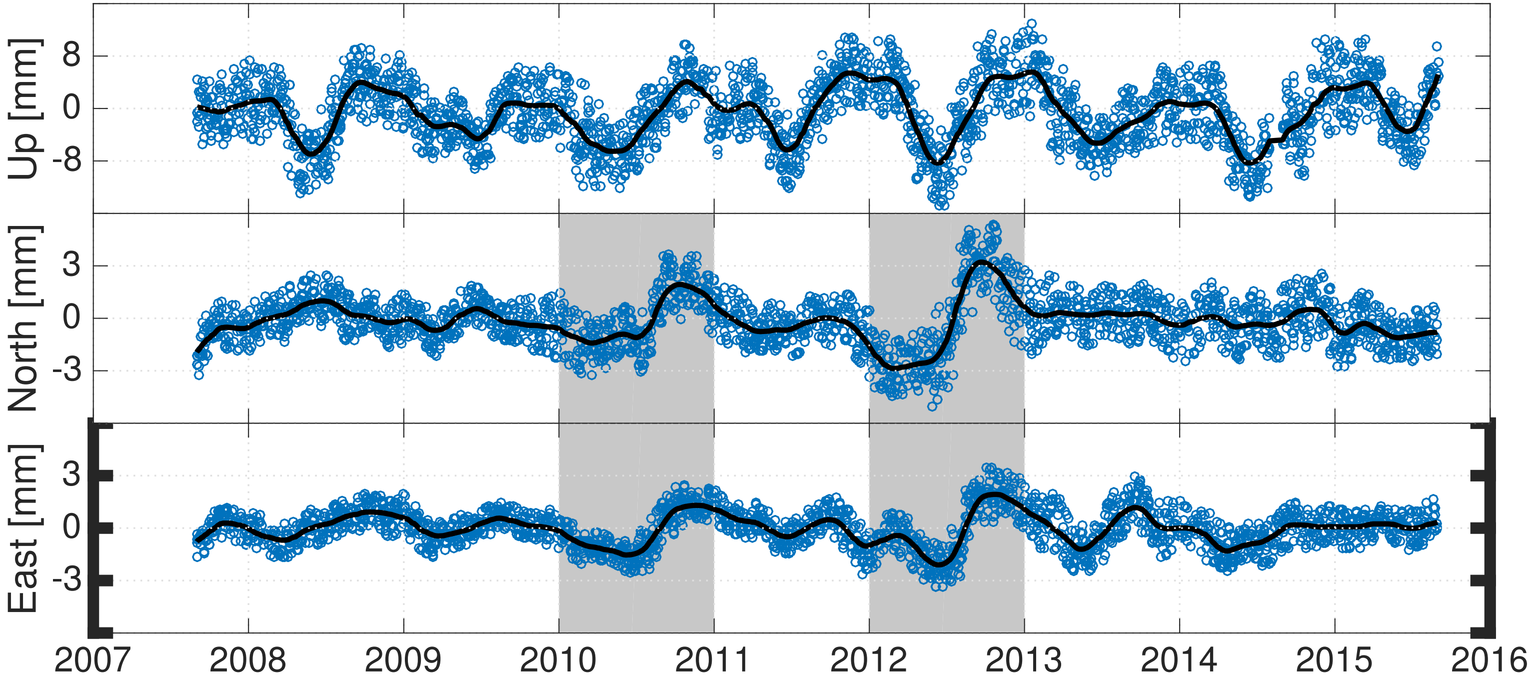




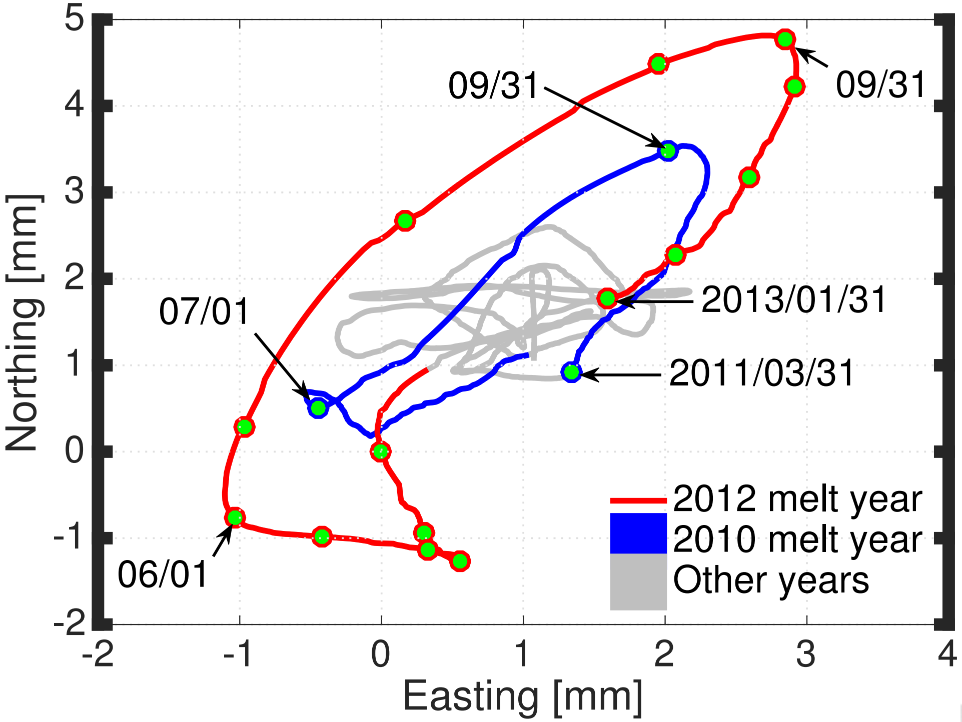
"Detectable" horizontal motions require a "large" mass anomaly with "asymmetry" in spatial distribution

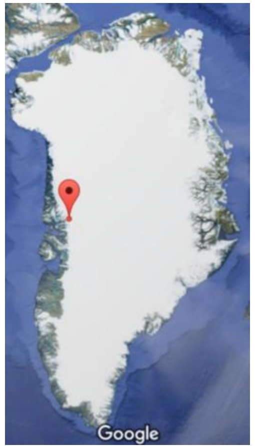


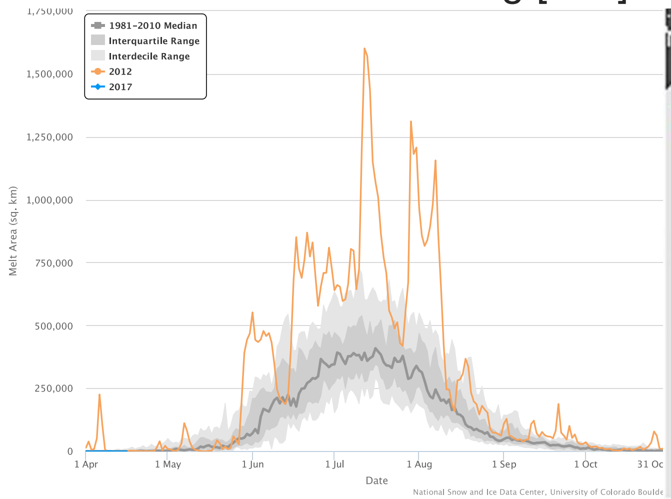
2. Question: What drives horizontal bed motion?



Data: Khan et al., 2016, *Sci. Adv.* ftp://ftp.spacecenter.dk/pub/abbas/GNET/v1/



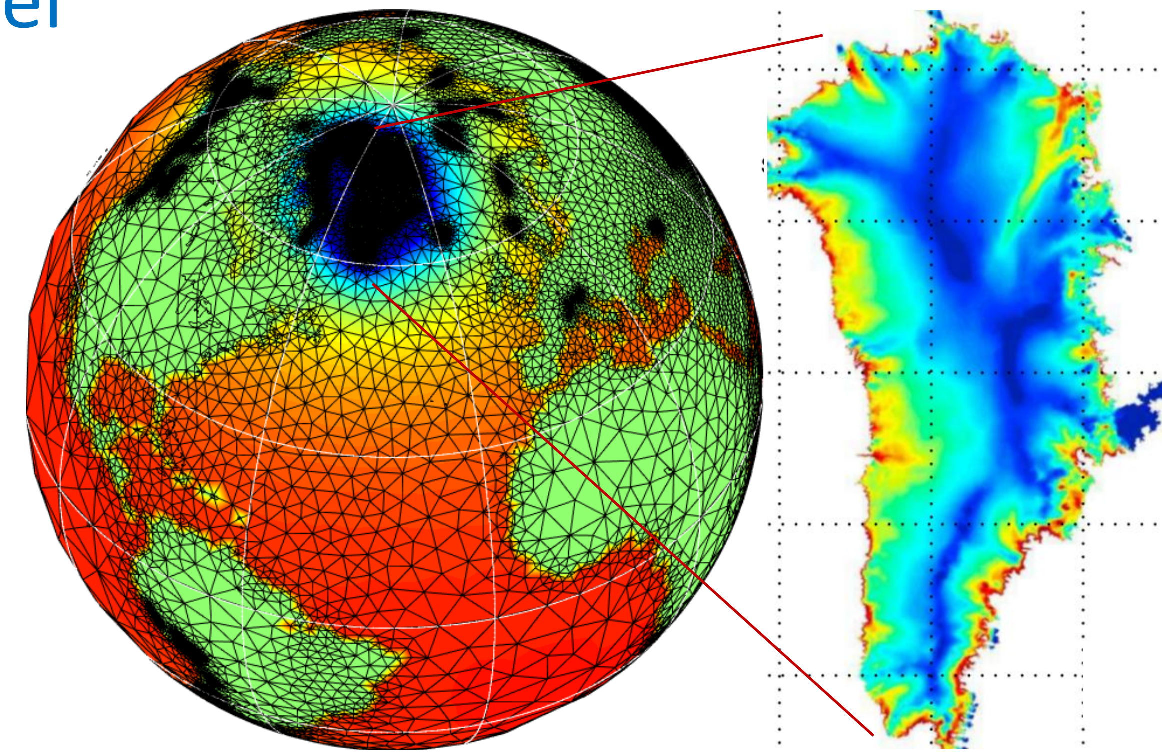


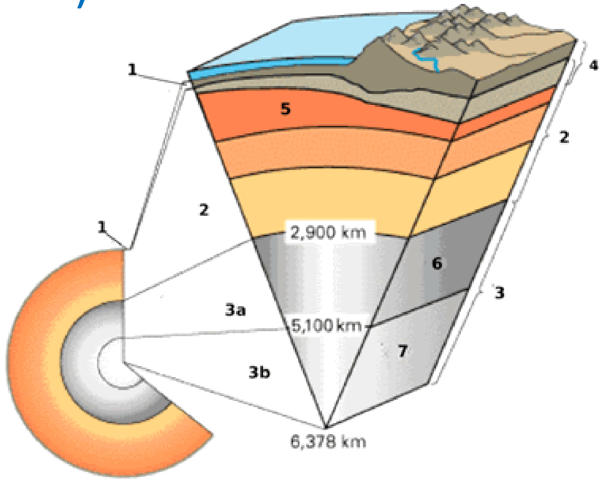


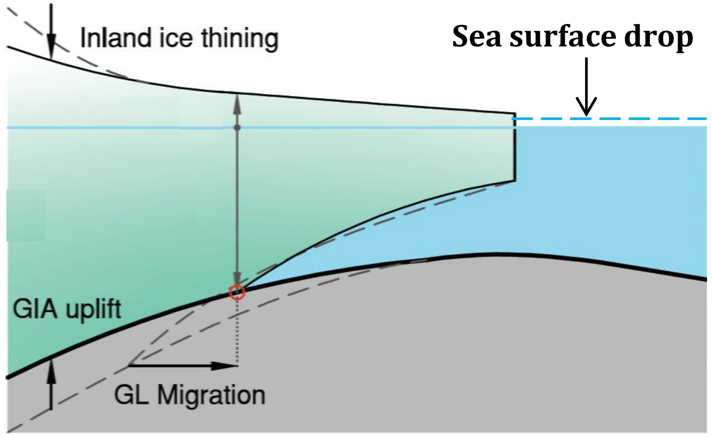
3. **ISSM:** Ice & Sea-level System Model

- High-order ice sheet model (Larour et al., 2012)
  - Ingests surface observables (e.g., ice speed)
  - Constrains glaciological unknowns (e.g., basal drag)
- Global geodetic model (Adhikari et al., 2016)
  - Ingests ice loads (or hydrological or tidal forcings)
  - Predicts relative sea-level, crustal deformation, etc.
- Systematic coupling of polar ice sheets
- Radially-stratified viscoelastic rotating Earth
  - Seismologically-constrained PREM (D&A, 1981)
  - Bayesian GIA models (Caron et al., 2018)

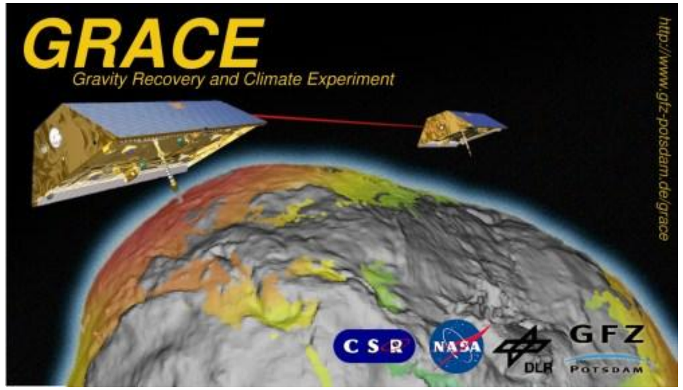
- ISSM Sea-level Workshop 2018
  - June 11-12 (after AOGS Annual Meeting)
  - University of Hawaii at Manoa
  - https://issm.jpl.nasa.gov







4.1 Results: GRACE-based forward modeling

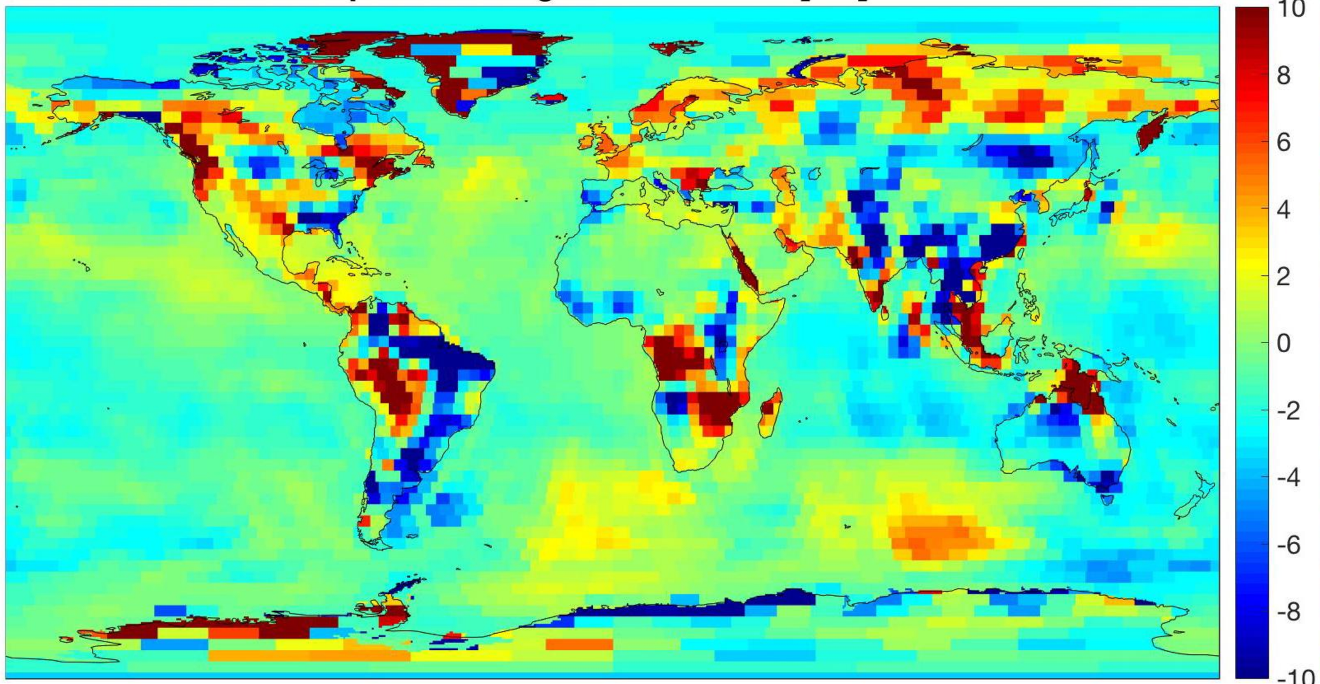


Global surface loads = Global GSM + Global GAC

GSM: Ice/water mass transport between/within continents & oceans

GAC: Non-tidal atmospheric/oceanic mass redistribution (ECMWF model)

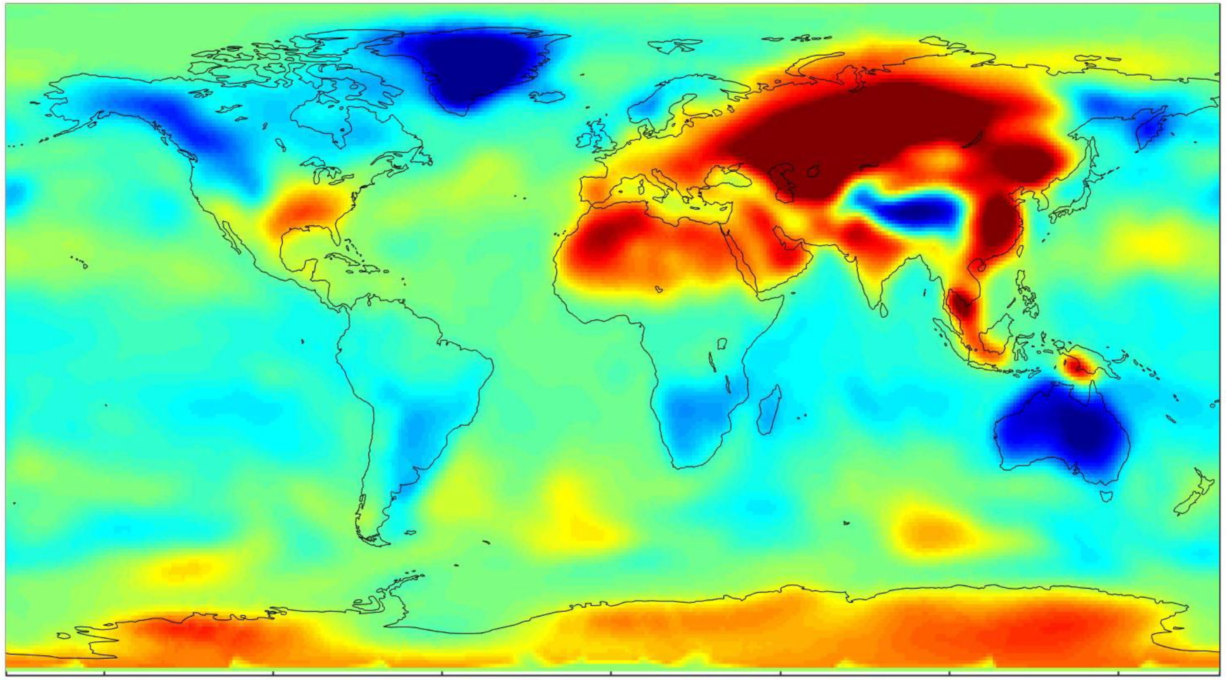
Water equivalent height of GSM load [cm]: 01/2008



https://grace.jpl.nasa.gov/

Watkins et al., 2015, *JGR*

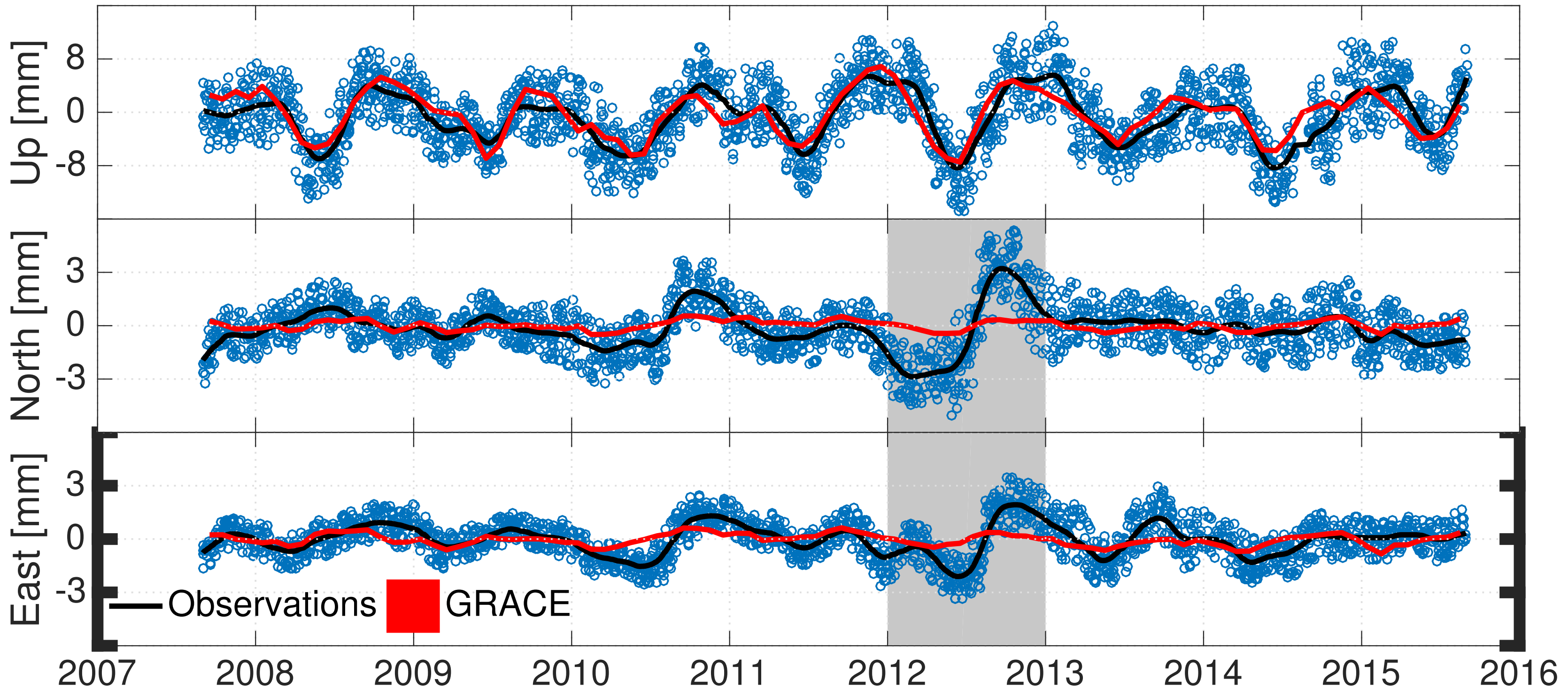
Water equivalent height of GAC load [cm]: 01/2008



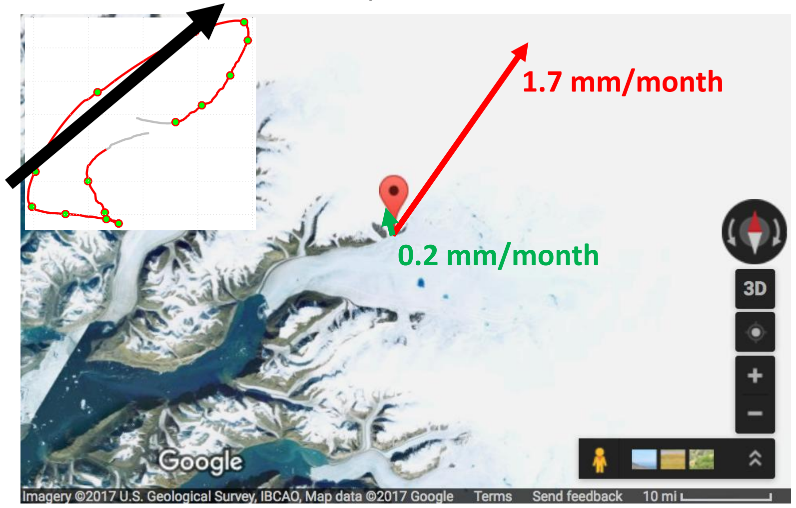
http://www.gfz-potsdam.de/en/grace/

See Flechtner & Dobslaw, 2013, *GRACE 327-750 AOD1B Product Description Document for Product Release 05*, GTZ, Potsdam, Germany

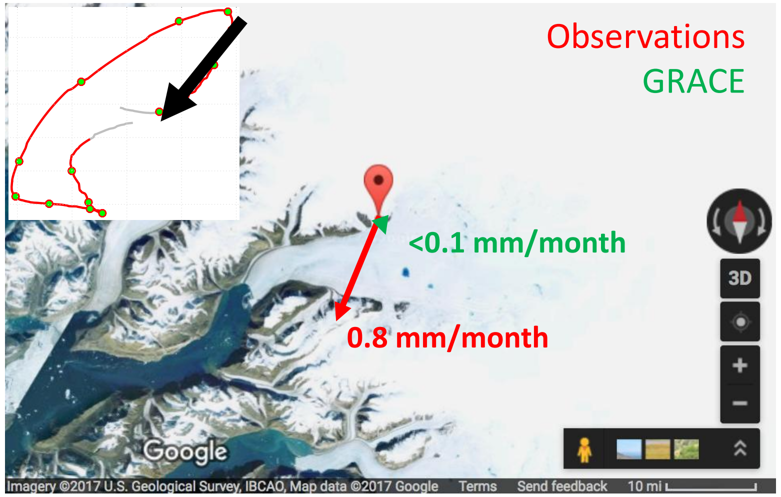
4.1 Results: GRACE does explain vertical, but not the horizontals



June – September 2012



October 2012 – January 2013



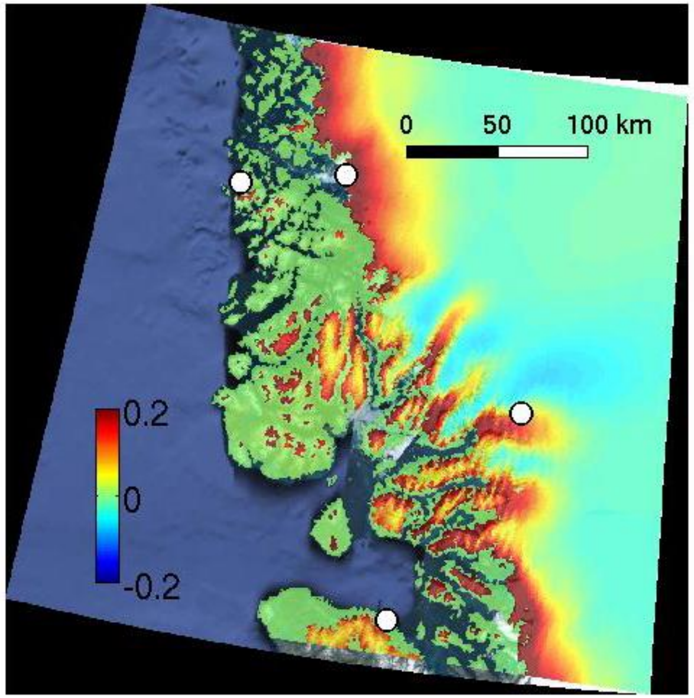
GRACE does not provide high enough resolution to capture "local asymmetry" in mass anomaly that is required to induce substantial horizontal motions at RINK station.

4.2 Results: SMB cannot explain horizontal motion either

Global surface loads = Global GAC + farfield GSM ~~+ local GSM~~ **+ local SMB**

SMB: Ice surface mass balance based on MAR & RACMO model

Water equivalent height of SMB [m]: 01/2008

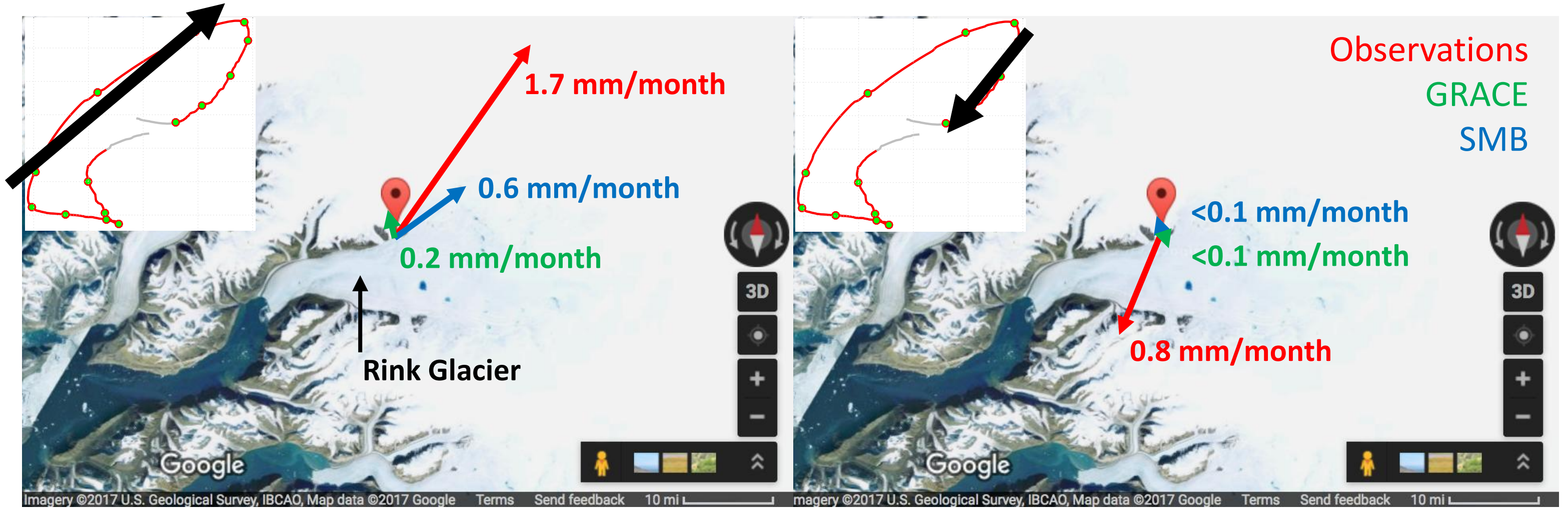


http://www.cryocity.org/mar-explorer.html

e.g., Fettweis et al., 2005, *Clim. Dyn.*

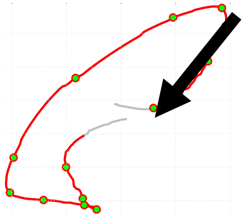
June – September 2012

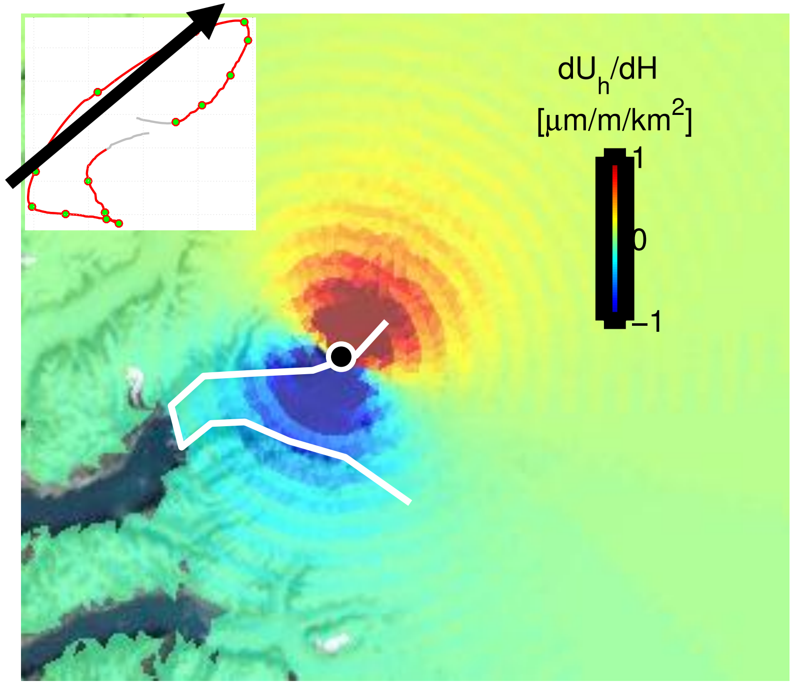
October 2012 – January 2013

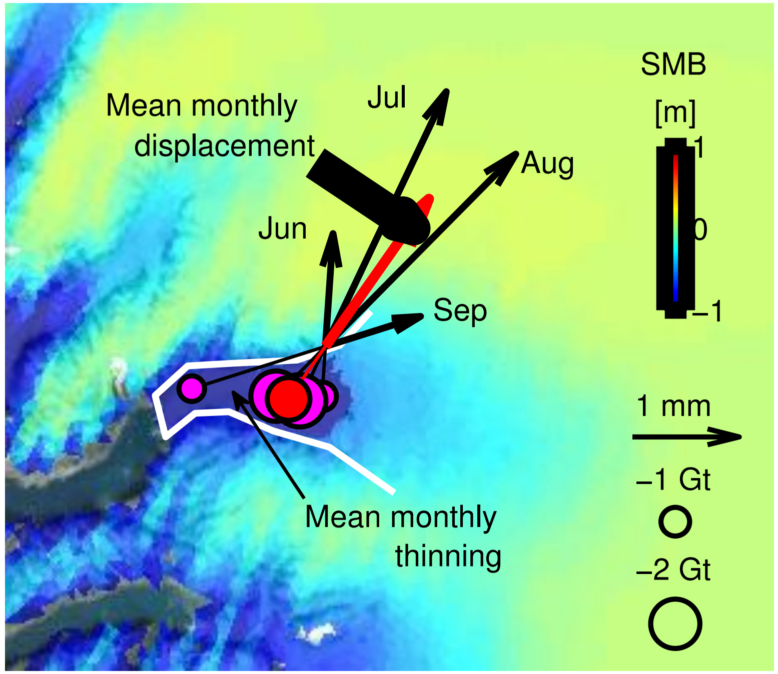


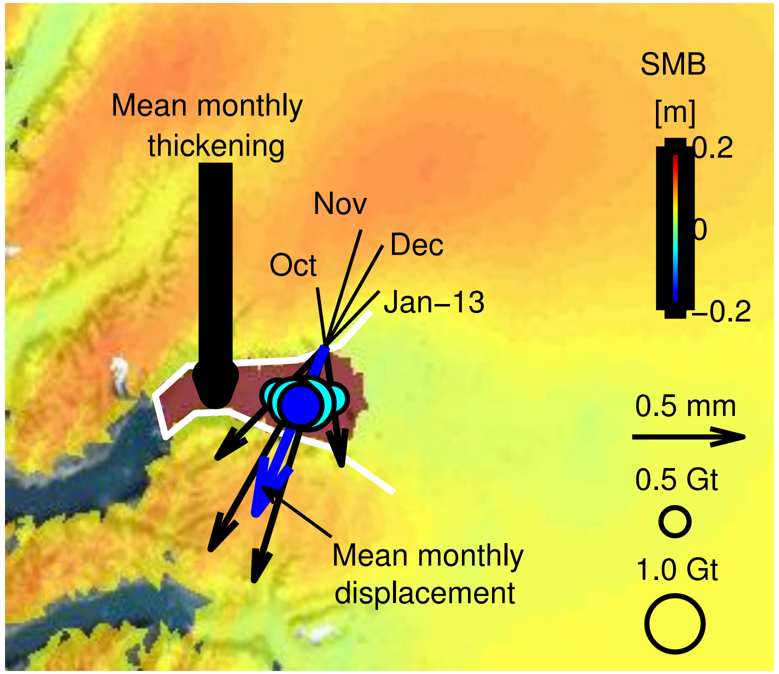
By the process of elimination, we are led to seek a coherent pattern in the dynamic mass transport through Rink Glacier.

4.3 Results: Inference of dynamic glacial mass transport

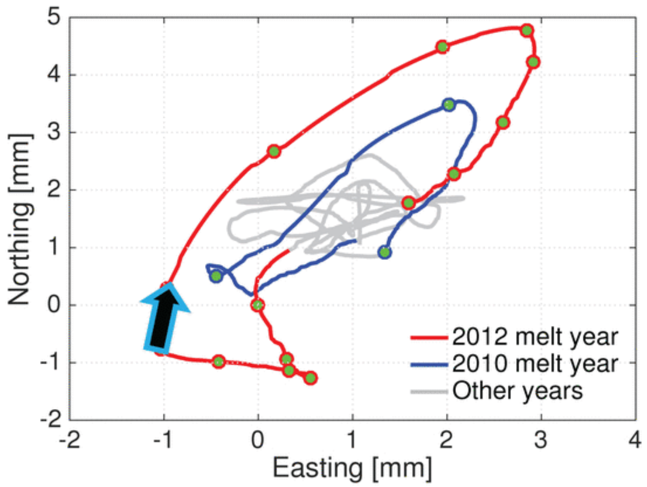


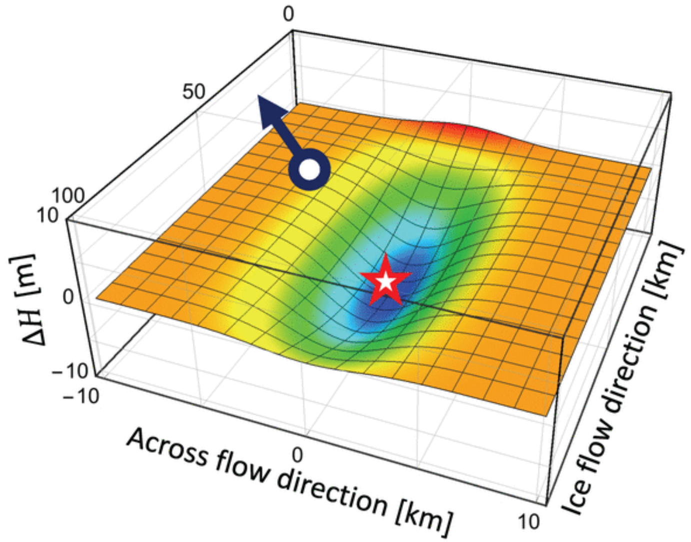






	Jun-Sep 2012	Oct 12 - Jan 13
Gt/month	-1.7 ± 0.5	0.8 ± 0.3
Sv	$\sim 6.4\times10^{-4}$	
km/month	7.1	2.8





…and, a glacial melt wave is detected!

5. Summary, implications, opportunities…

- Ice mechanics
  - Ours is the first detection of glacial melt waves in any of Greenland or Antarctic glaciers.
  - A total of 6.7 Gt of ice was dumped to the oceans during 4 summer months in 2012, implying that glaciers can indeed transport substantial mass on short timescales!
- Climate & sea-level
  - Increased frequency of amplified seasonal waves will have ramifications for future sea-level rise.
- Geodesy
  - A single station bedrock GPS may be sufficient to quantify glacial mass transport.
  - An engineered GPS network, combined with space measurements of crustal deformation (e.g., NISAR), should revolutionize the way we constrain mass in dynamic ice-sheet models.

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