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Herceg, Matija; Tscherning, Carl Christian; F. Levinsen, Joanna

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Greenland mass variation from GOCE gradients as changes in reduced point masses

Matija Herceg[1], Carl Christian Tscherning[2], Joanna F. Levinsen[3]

[1]*IGN, University of Copenhagen, Denmark*

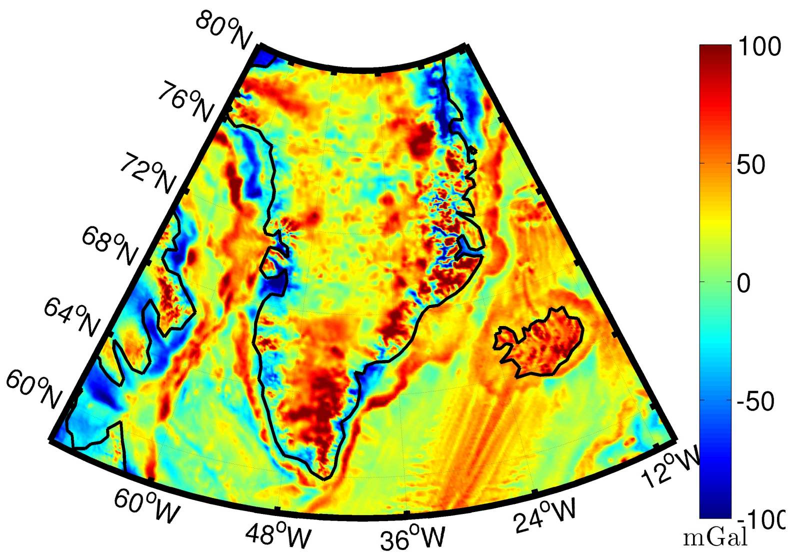
[2]*Niels Bohr Institute, University of Copenhagen, Denmark*

[3]*DTU Space, Technical University of Denmark, Denmark*

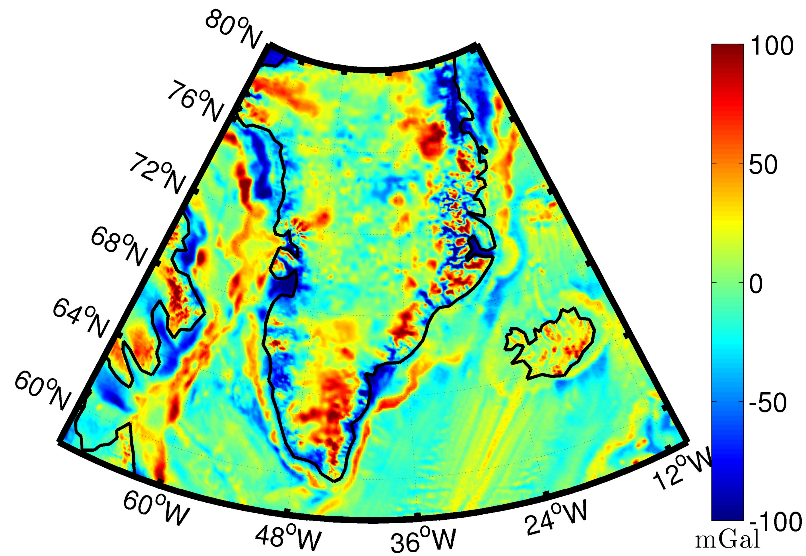
Motivation

- The GOCE gradients may potentially be used for determination of residual masses in local regions, by the use of Reduced Point Mass (RPM) method
- Reduced Point Masses can not be interpreted directly in the term of mass changes but may aid in localizing the areas where (positive or negative) changes takes place.
- Is it possible to track rapid mass change of glacier in Greenland by GOCE gradients?

EGM2008 gravity anomaly

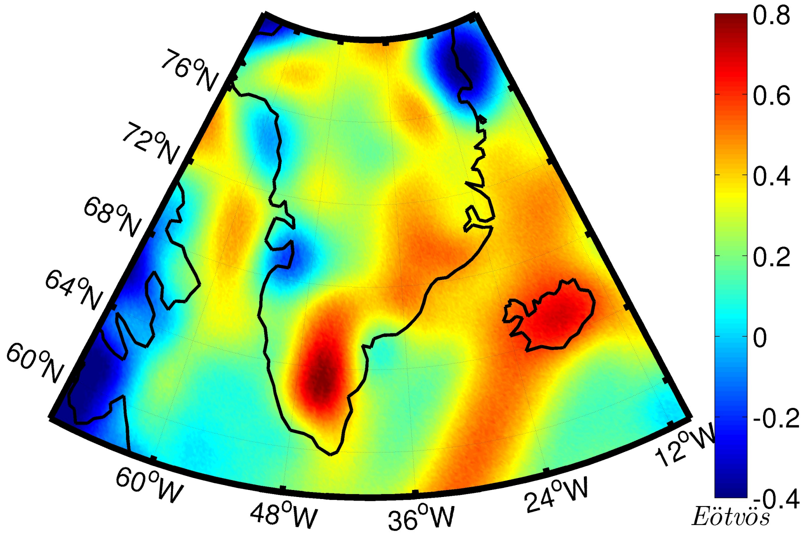


EGM2008 gravity anomaly

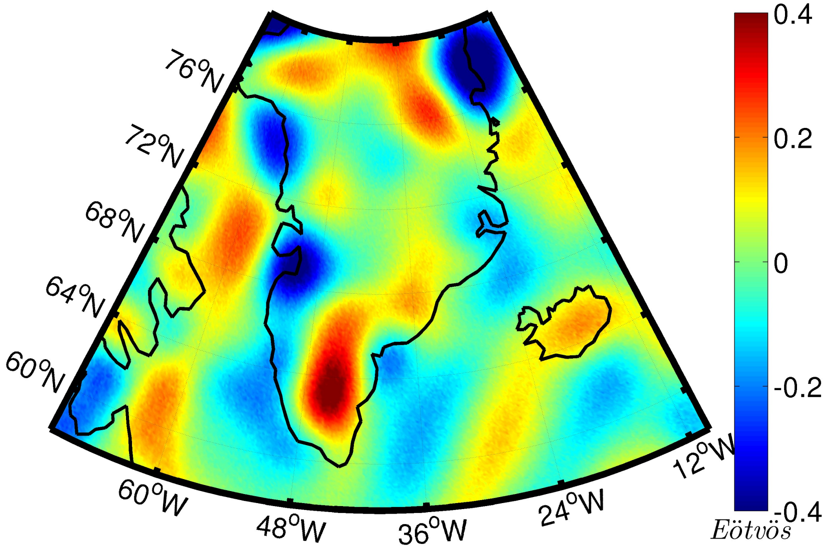


EGM2008 truncated gravity anomaly (contribution up to spherical harmonic degree and order 36 is subtracted)

GOCE T_{zz} gravity gradients from 11.2009. - 06.2010.

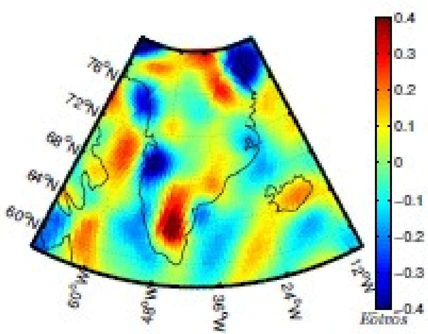


GOCE Tzz gravity gradients

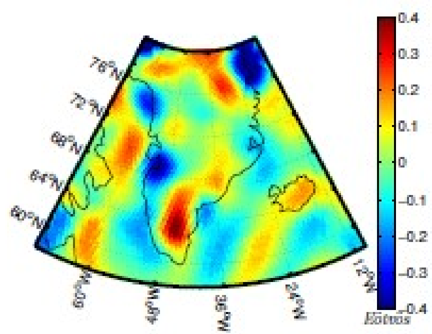


GOCE Tzz truncated gravity gradients (contribution up to spherical harmonic degree and order 36 is subtracted)

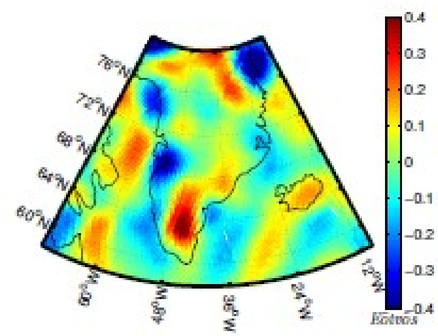
Monthly GOCE T_{zz} gravity gradients



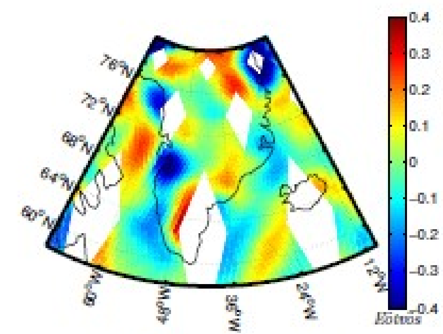
(a) November, 2009.



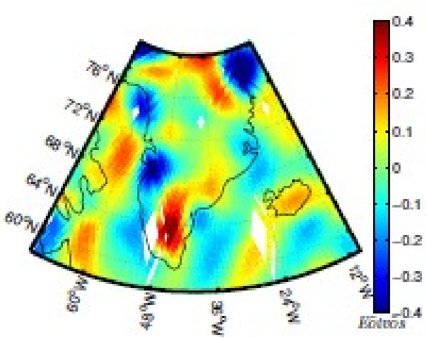
(b) December, 2009.



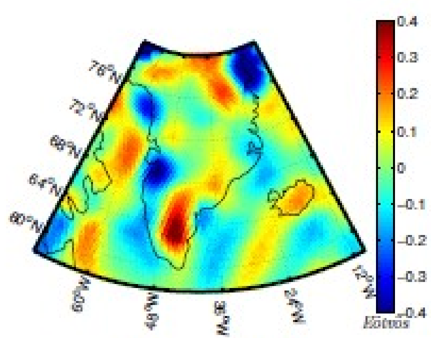
(c) January, 2010.



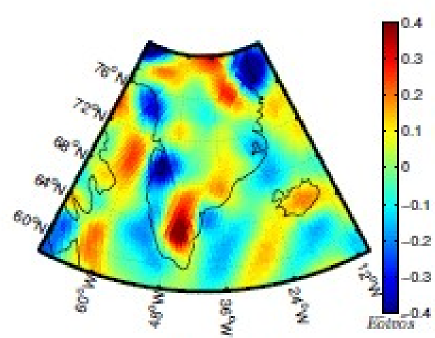
(d) February, 2010.



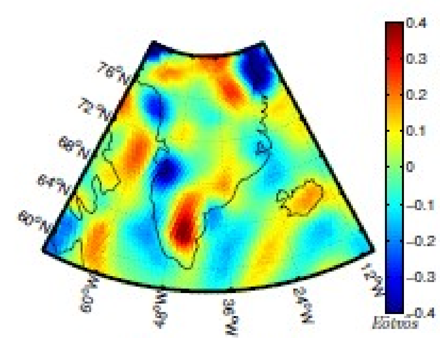
(e) March, 2010.



(f) April, 2010.

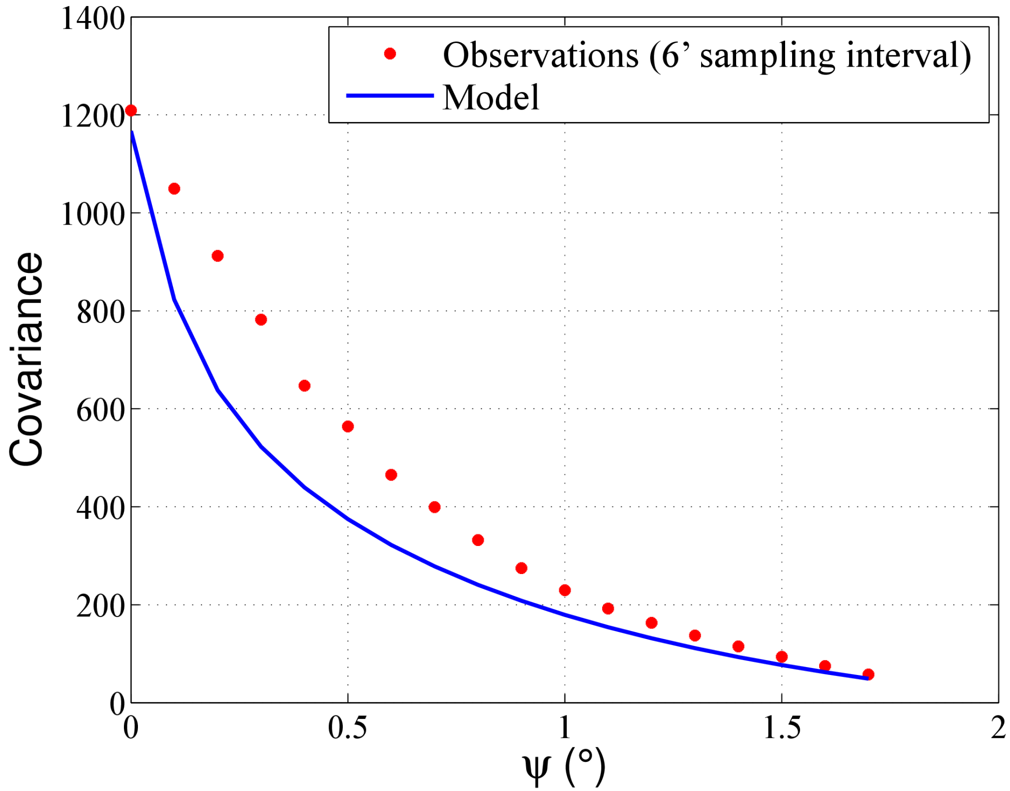


(g) May, 2010.

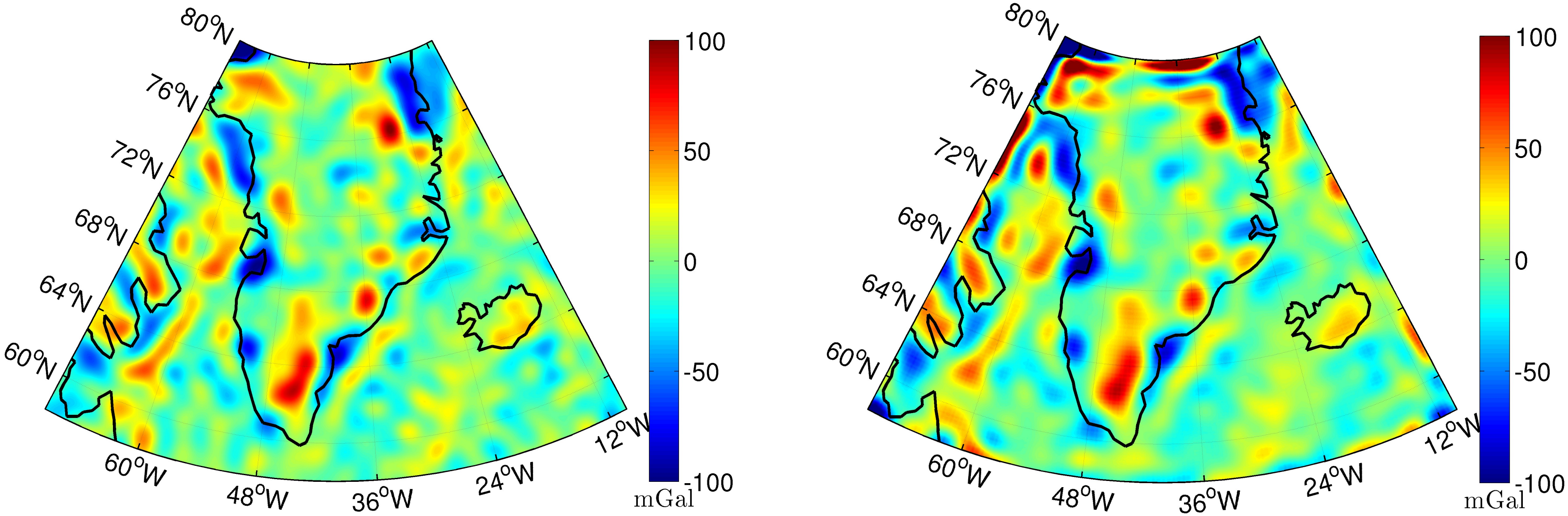


(h) June, 2010.

Empirical covariance function based on GOCE Tzz gradients



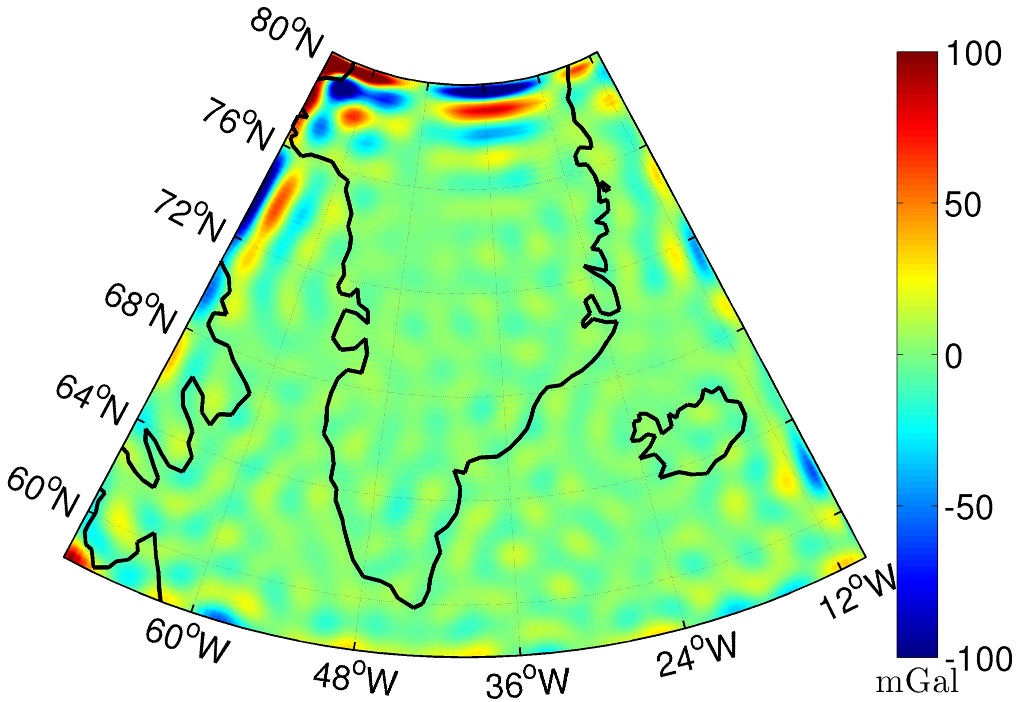
Comparison of gravity anomaly prediction with GOCE T_{zz} gravity gradients (Dec 2009.)



Collocation

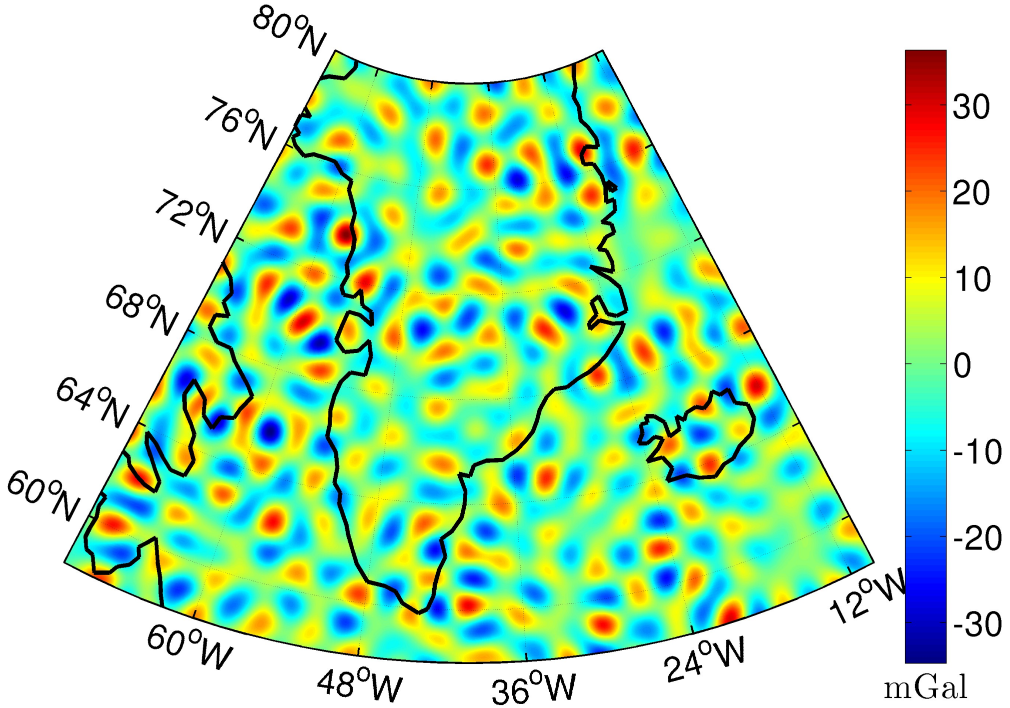
Reduced point mass

Comparison of gravity anomaly prediction with GOCE T_{zz} gravity gradients (Dec 2009.)

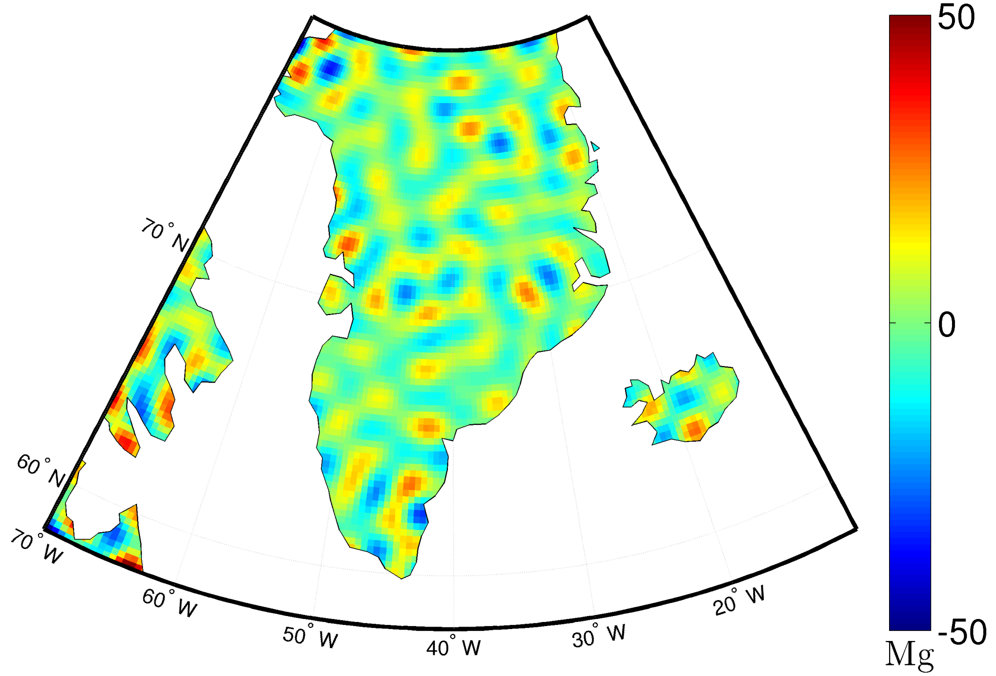


Difference (Collocation - Reduced point mass)

Gravity anomaly change from November 2009. to June 2010. calculated by GOCE Tzz gradients



Prediction of mass change by GOCE Tzz gradients and RPM from November 2009. to June 2010.



Test region - Jakobshavn Isbræ glacier

- Rapidly changing outlet glacier in Greenland
  - NASA Earth Observatory's IceBridge program indicates that Greenland's Jakobshavn Isbræ glacier has the potential to influence sea level rise more than any other single feature in the Northern Hemisphere
  - Lowering at rates of 30-35 m/yr (Levinsen et al., 2013.)

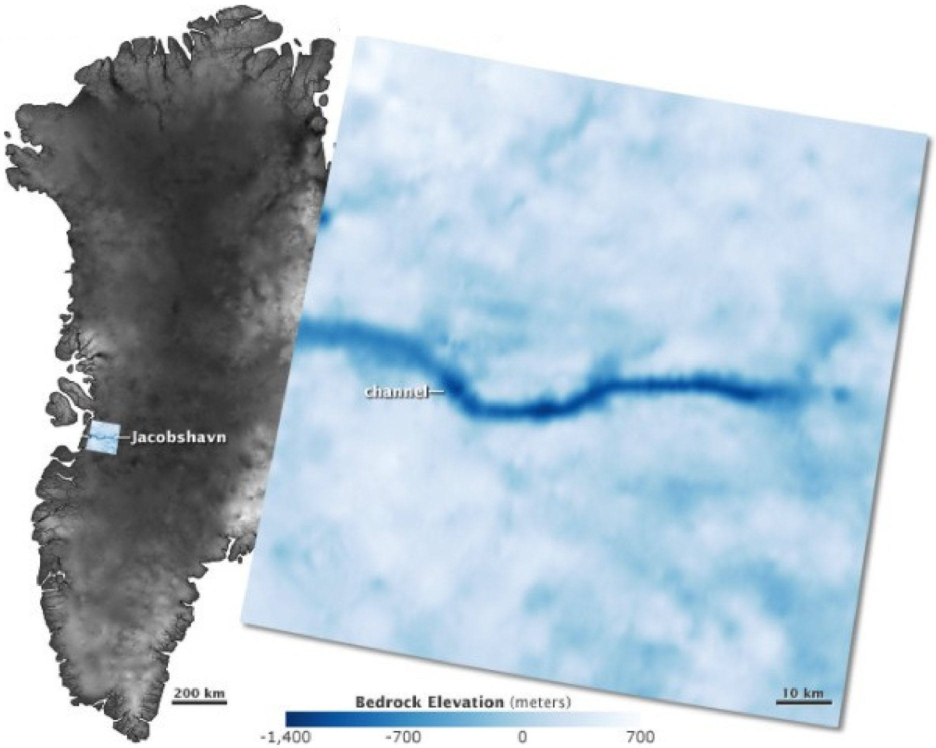
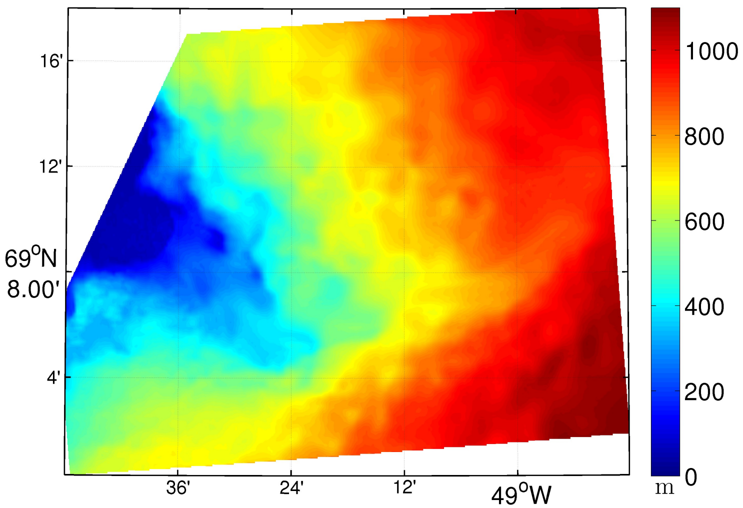
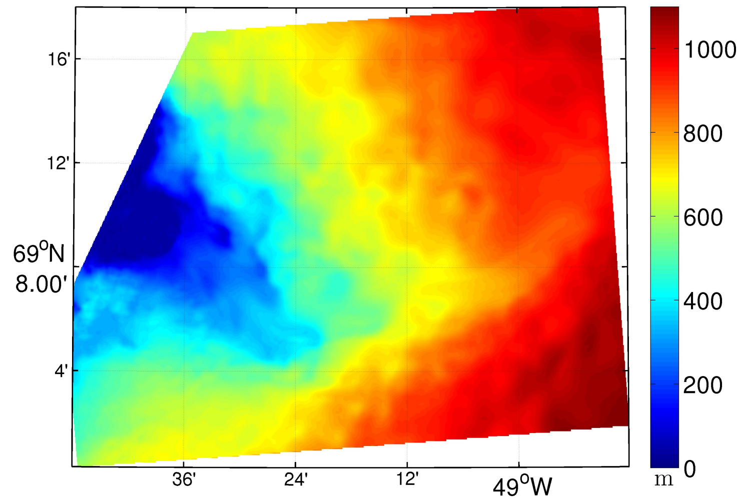


Figure credit: NASA Earth Observatory

Test region - Jakobshavn Isbræ glacier

- High-resolution (~100 m) surface elevations and elevations changes over rapidly changing outlet glaciers in Greenland
  - Derived from combination of the complimentary characteristics of laser altimeter data and stereoscopic Digital Elevation Models (Levinsen et al., 2013.)





Calculation of gravity anomaly change

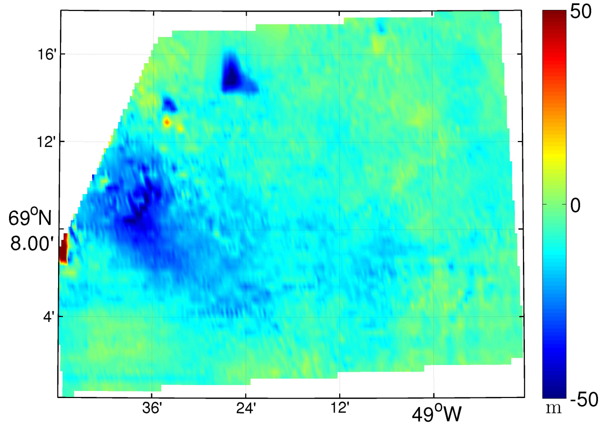
- Method used

  1.) Gravity anomaly coming from changes in topography can be approximated by simple Bouguer correction

  2.) Gravity anomaly calculated by GRAVSOFT TC program

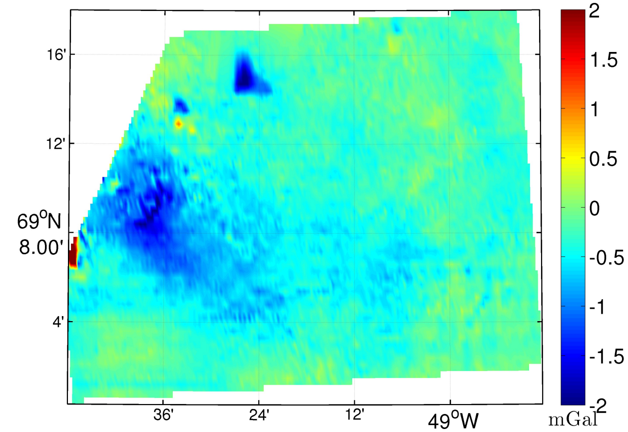
  - Calculation of direct topographic effect of all masses above reference level, assuming the density to be constant (0.92 g/cm^3).

Gravity anomaly change calculated from change in Greenland ice mass

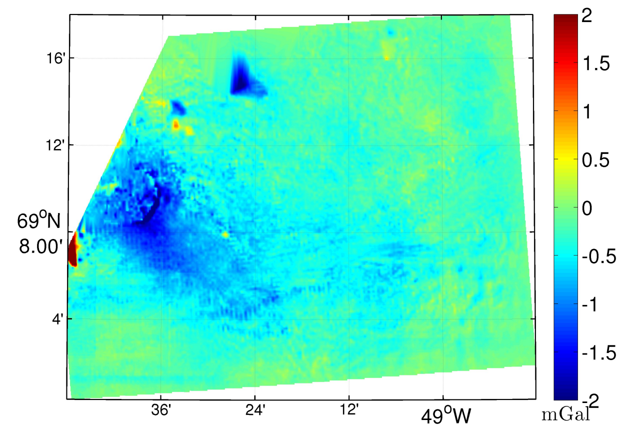


Change in height of Jakobshavn Glacier ice from 2007-2008 (Levinsen et al., 2013.)

Gravity change from height change by Bouguer

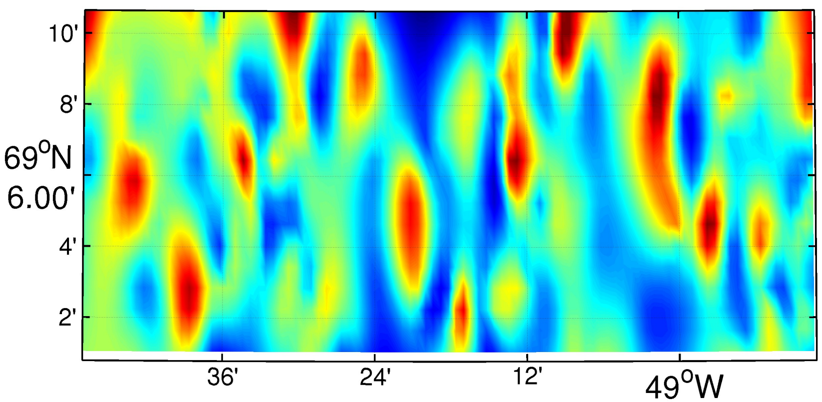


Gravity change from height change by TC

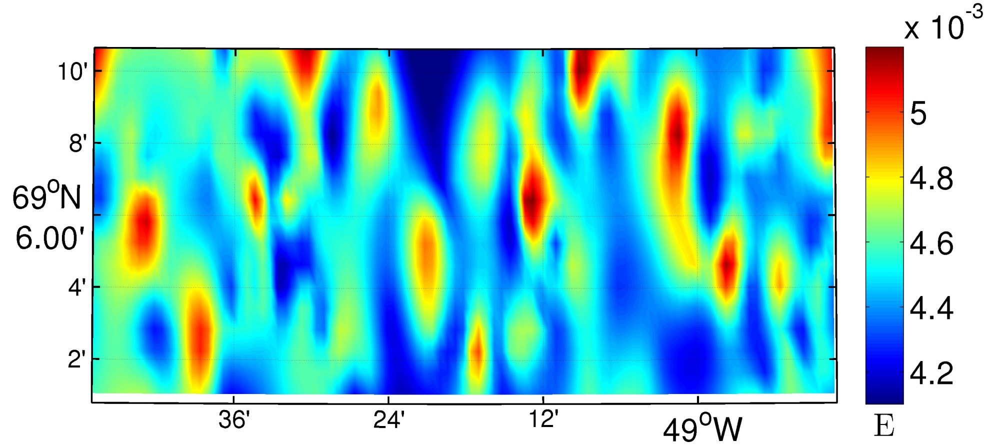


Change in height of 50m corresponds to the gravity change of 2 mGal.

Jakobshavn Glacier Tzz gravity gradient at satellite altitude calculated by GRAVSOFT TC program

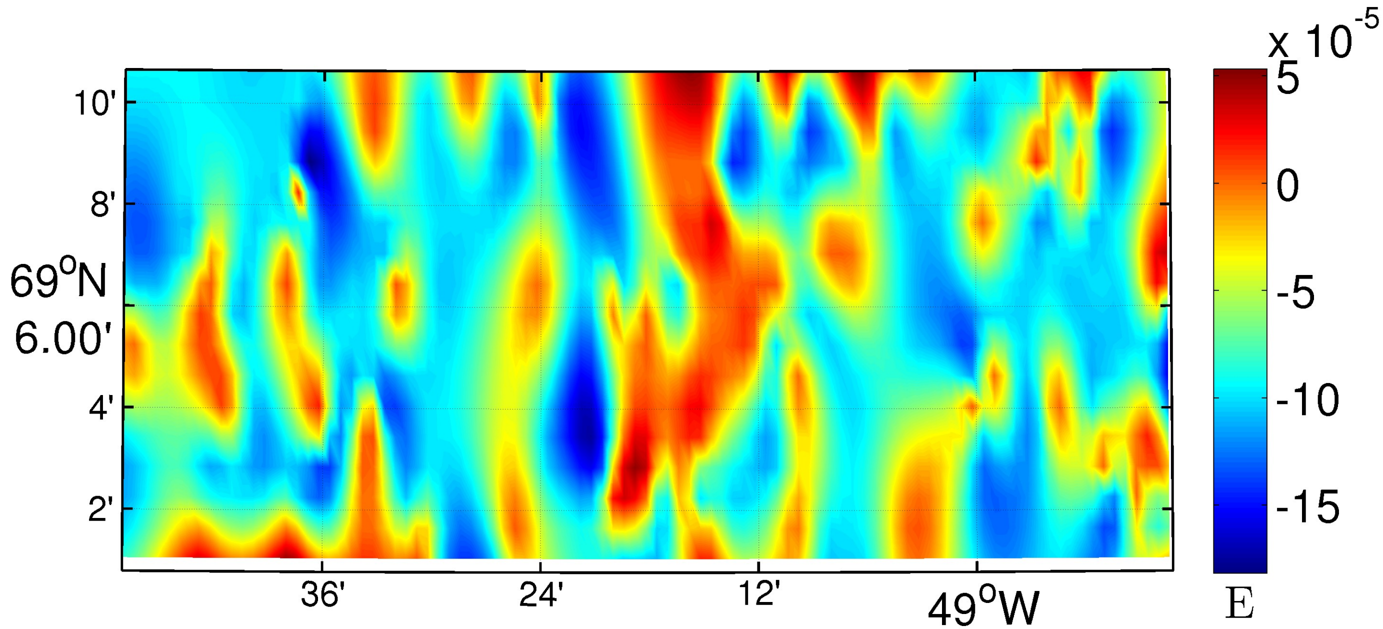


Tzz for 08.2007.



Tzz for 08.2008.

Jakobshavn Glacier Tzz gravity gradient change resulting from change in ice mass calculated by RPM



- The maximal vertical gradient change at satellite altitude for the Jakobshavn area (2007 - 2008) is only 0.2mE
- The gradients observed by GOCE has a minimum error of 3mE for the along track component

Conclusion and future work

- The estimated gravity anomalies are very similar for the two methods used
- The maximal gravity changes at the ground are between 2 and 4mGal for the period considered. The error of estimation of gravity anomalies from the GOCE gradient data using only Tzz with an associated error of 20mE is 11mGal
- Using more gradient components in the GRF would certainly reduce this error, probably down to 5-6mGal
- The maximal vertical gradient change at satellite altitude for the Jakobshavn area (2007 - 2008) is only 0.2mE. The gradients observed by GOCE has a minimum error of 3mE for the along track component
- combination of all 4 components could lower error to 1mE
- With a period of 5 years it could be possible to to observe this small signal (4 years of observations to be available at the end of 2013)