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

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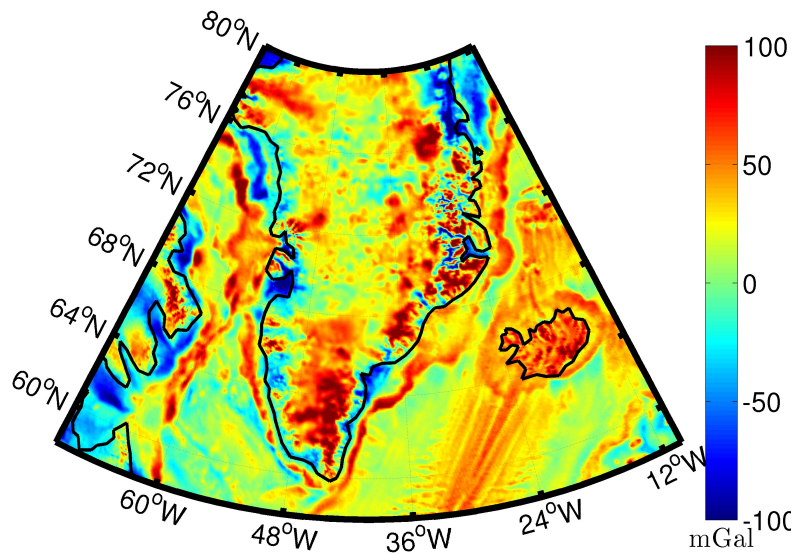
<sup>3</sup>*DTU Space, Technical University of Denmark, Denmark*

# Motivation

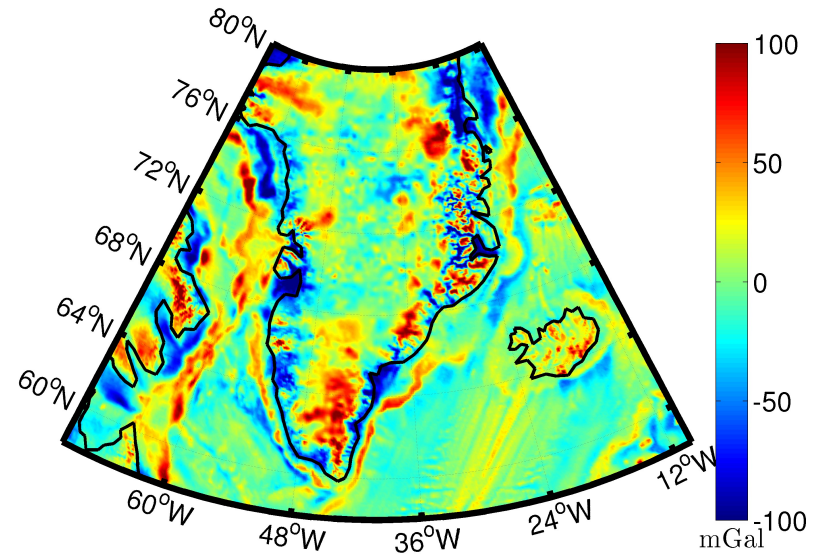
- The GOCE gradients may potentially be used for determination of residual masses in local regions, by the use of Reduced Point Mass (RPM) method
- Reduced Point Masses can not be interpreted directly in the term of mass changes but may aid in localizing the areas where (positive or negative) changes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



## EGM2008 gravity anomaly

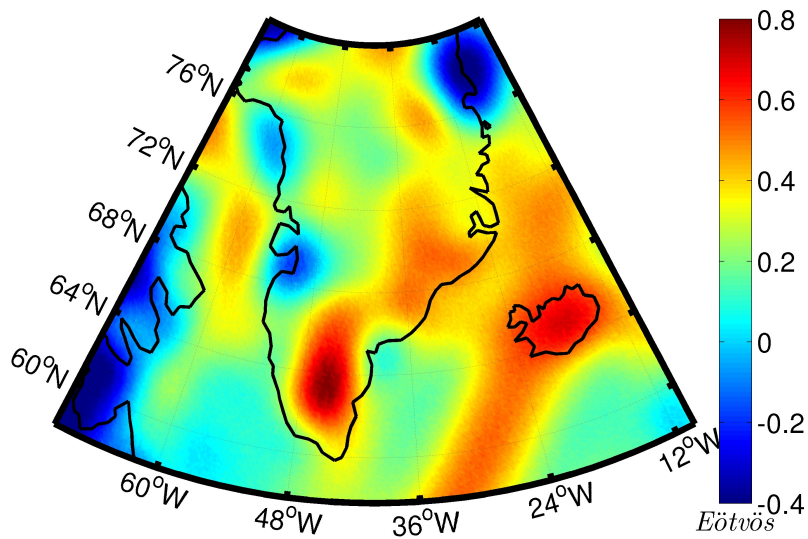


EGM2008 gravity anomaly

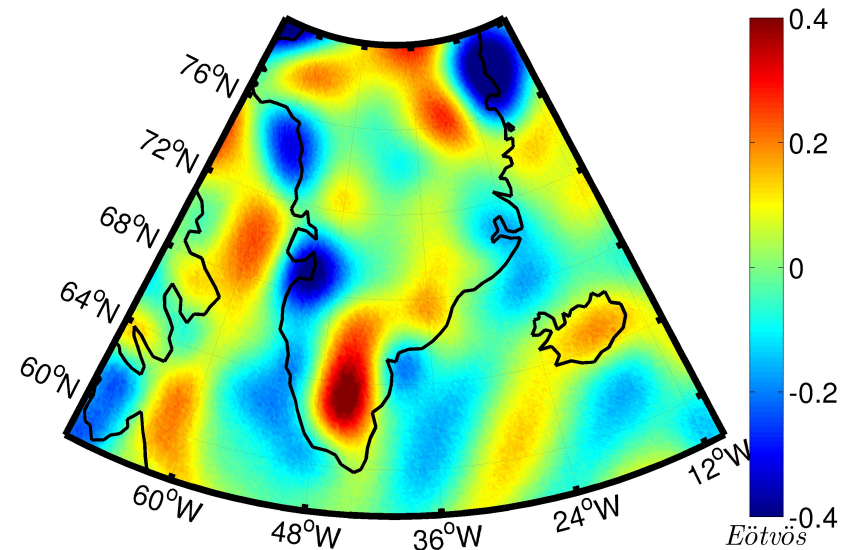


EGM2008 truncated gravity anomaly  
(contribution up to spherical harmonic degree and order 36 is subtracted)

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

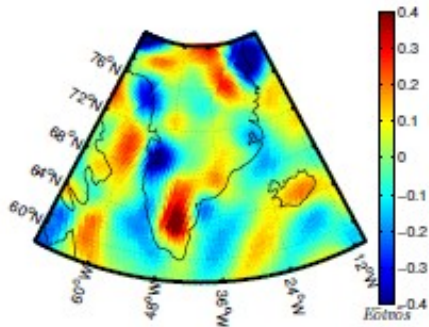


GOCE  $T_{zz}$  gravity gradients

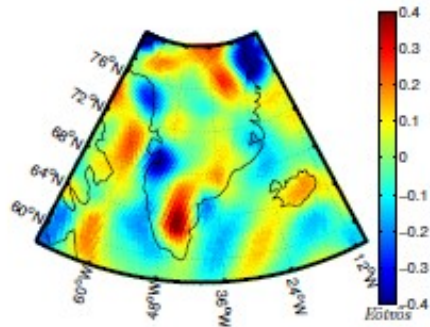


GOCE  $T_{zz}$  truncated gravity gradients  
(contribution up to spherical harmonic degree and order 36 is subtracted)

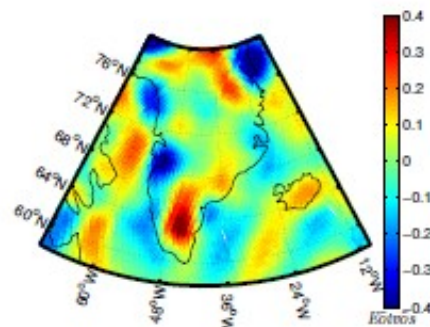
# Monthly GOCE $T_{zz}$ gravity gradients



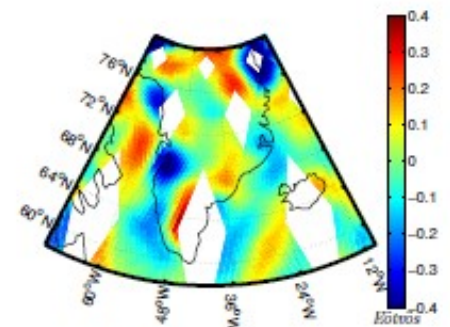
(a) November, 2009.



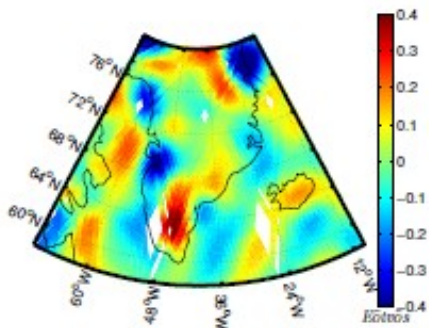
(b) December, 2009.



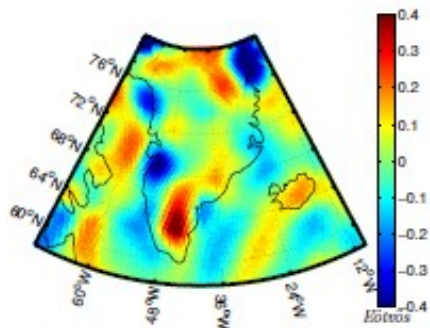
(c) January, 2010.



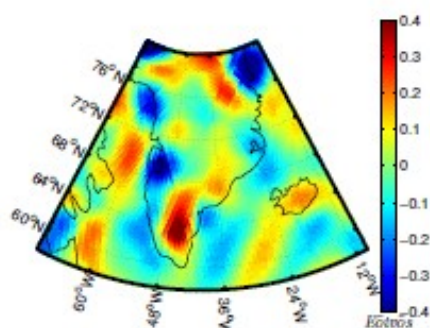
(d) February, 2010.



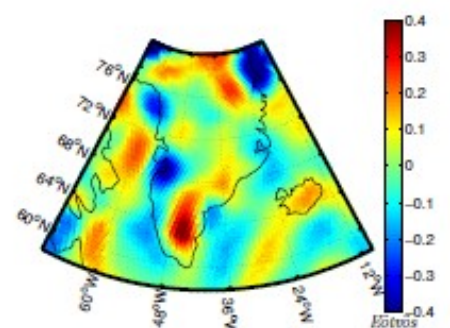
(e) March, 2010.



(f) April, 2010.



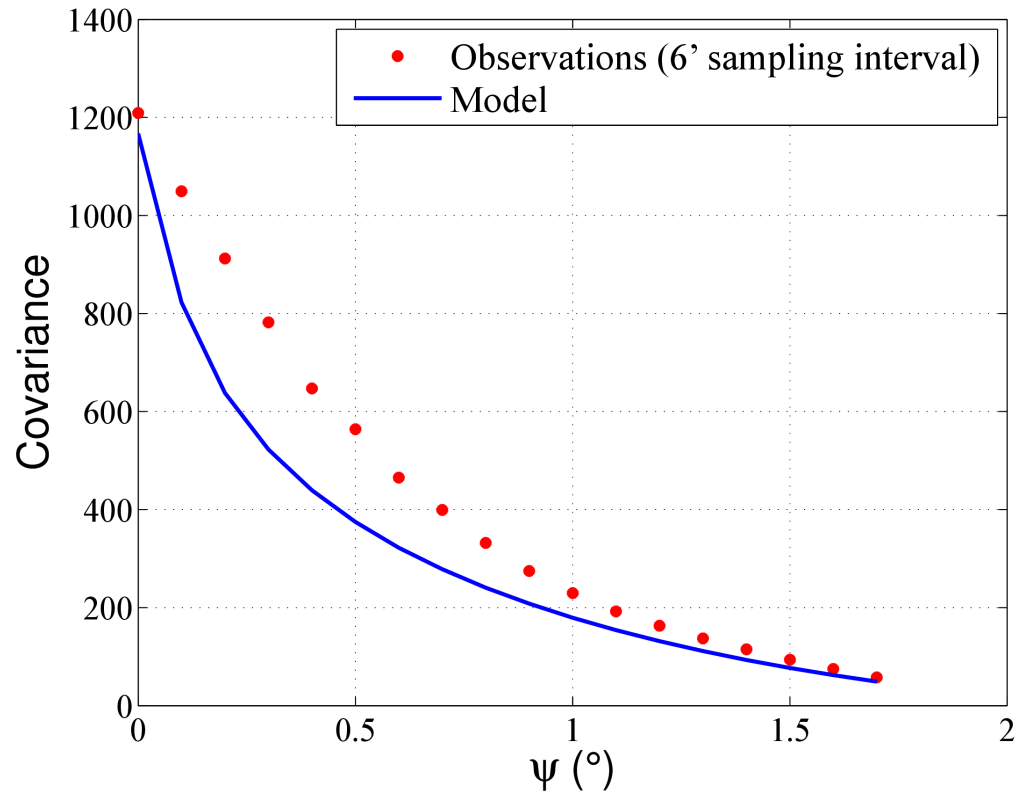
(g) May, 2010.



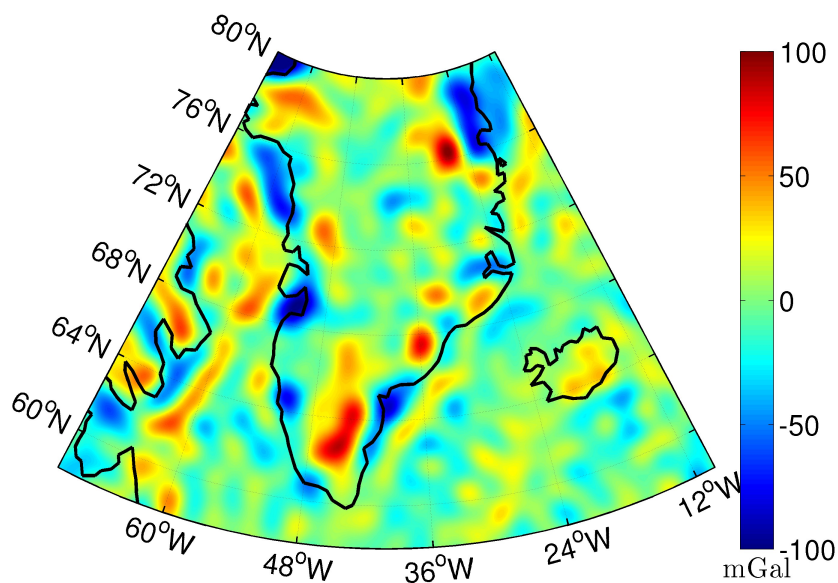
(h) June, 2010.



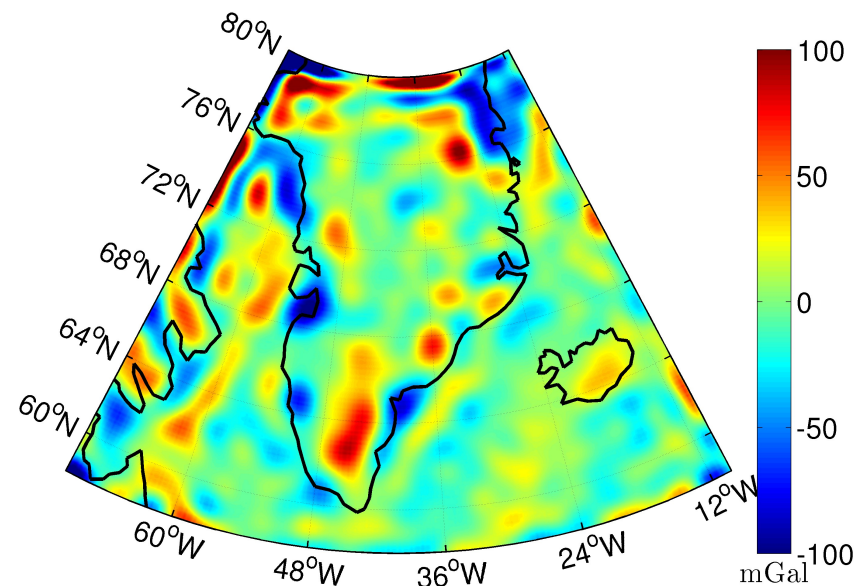
# Empirical covariance function based on GOCE Tzz gradients



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



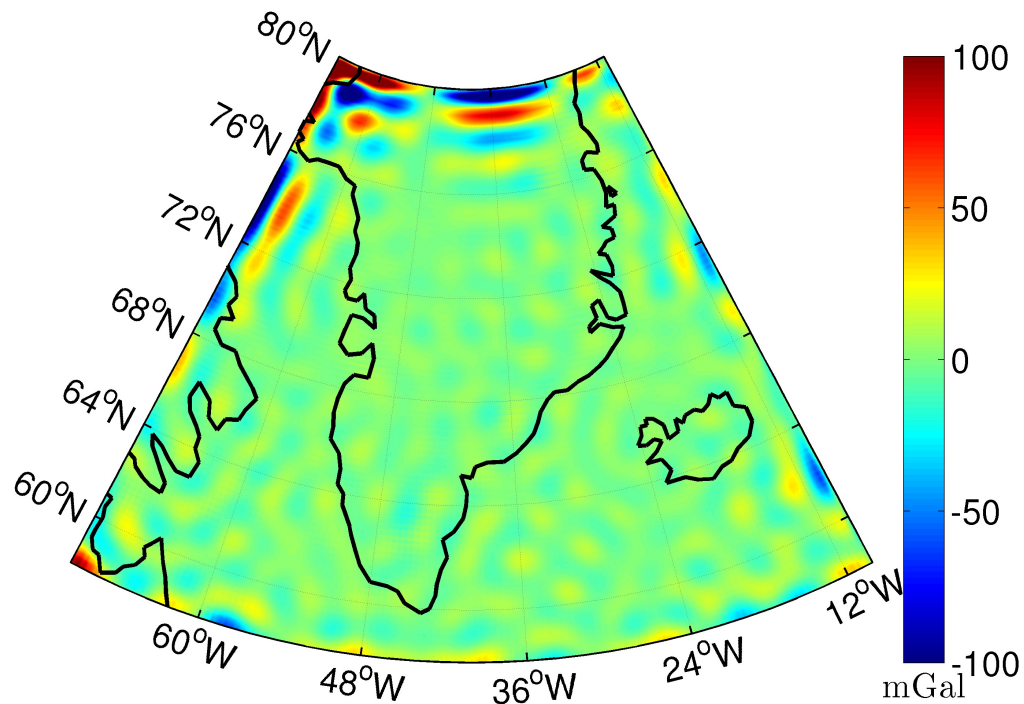
Collocation



Reduced point mass

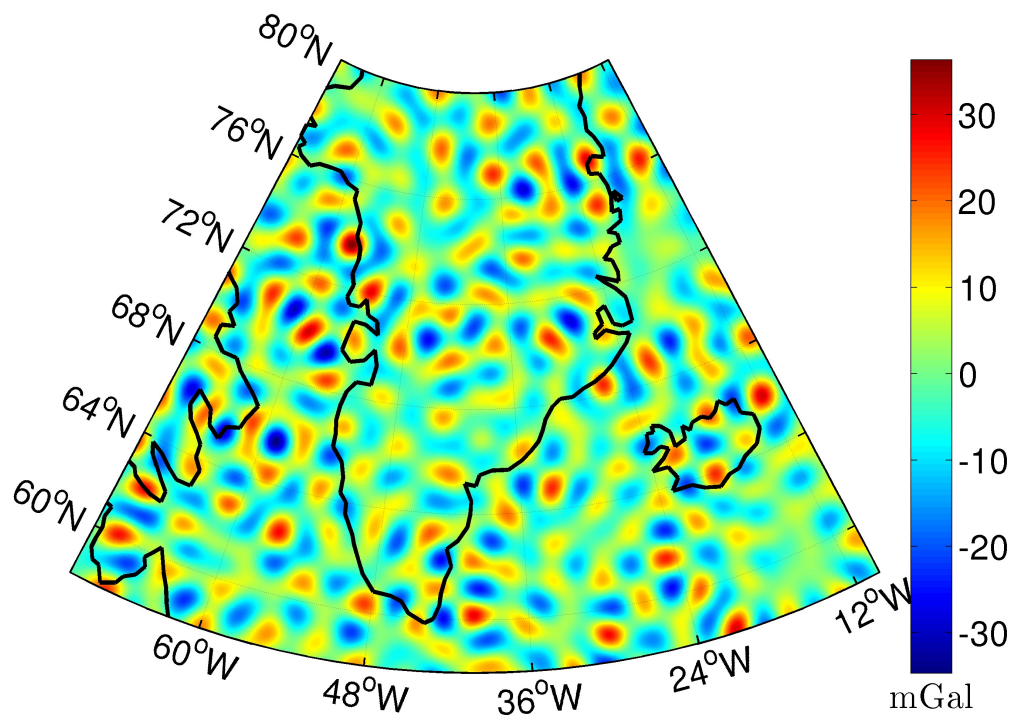


# Comparison of gravity anomaly prediction with GOCE $T_{zz}$ gravity gradients (Dec 2009.)

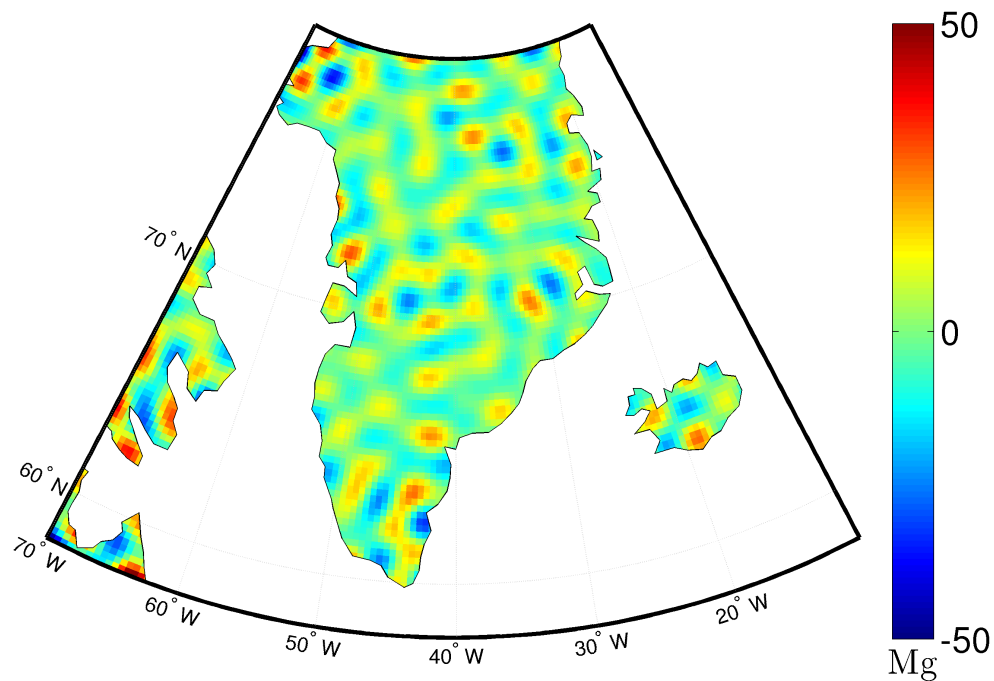


Difference (Collocation - Reduced point mass)

## 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.)

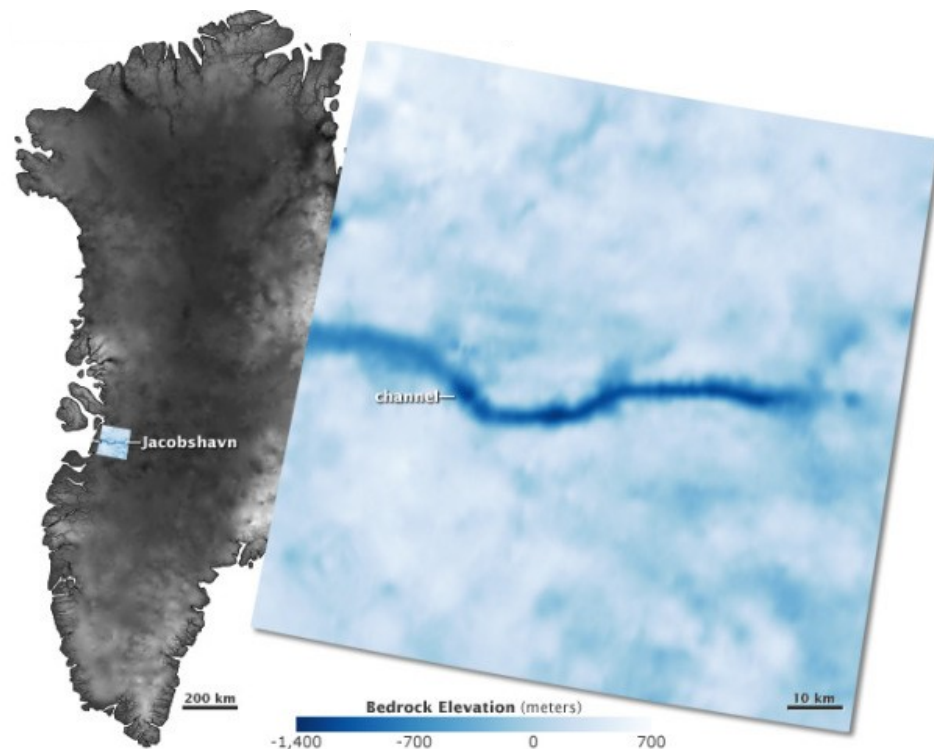
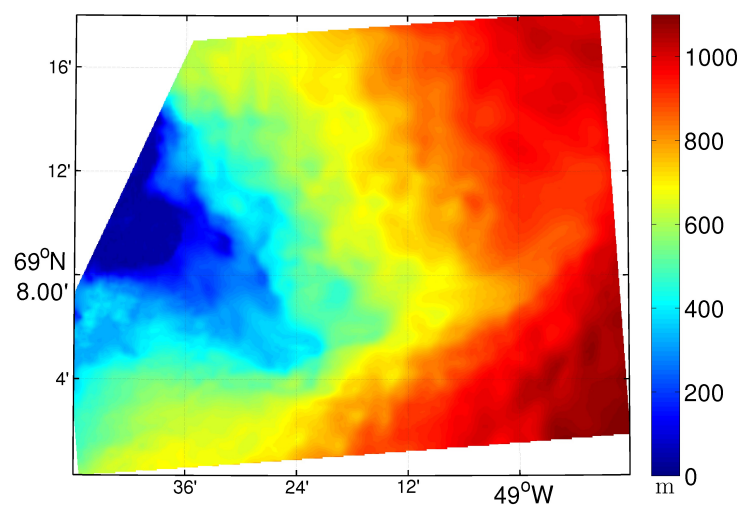
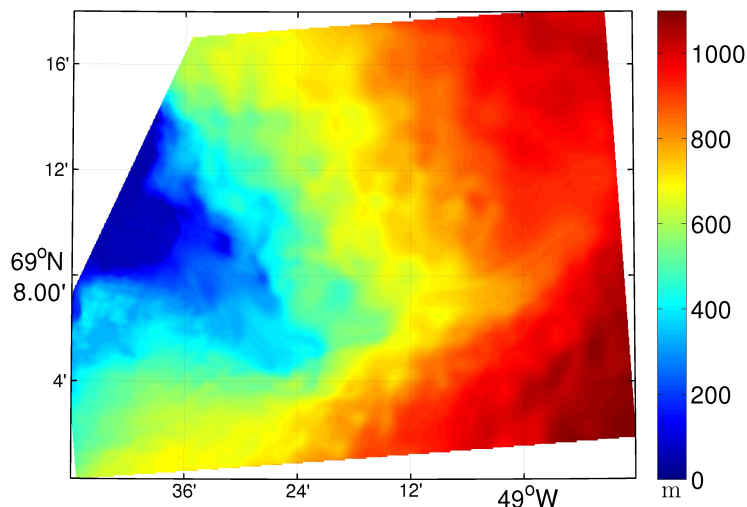


Figure credit: NASA Earth Observatory

## Test region - Jakobshavn Isbræ glacier

- High-resolution ( $\sim 100$  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.)

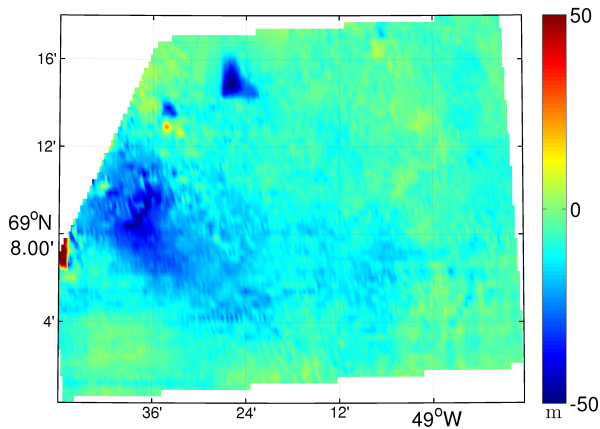


# Calculation of gravity anomaly change

- 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 ( $0.92 \text{ g/cm}^3$ ).

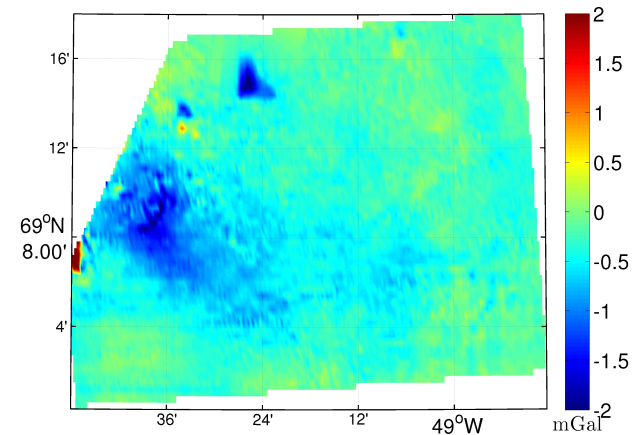


# Gravity anomaly change calculated from change in Greenland ice mass

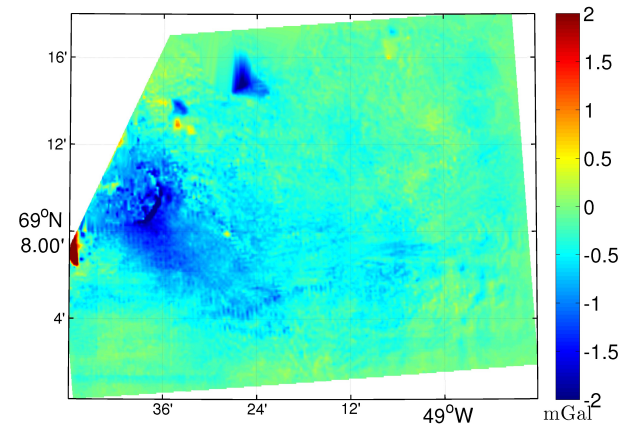


Change in height of Jakobshavn Glacier ice from 2007-2008 (Levinsen et al., 2013.)

Gravity change from height change by Bouguer



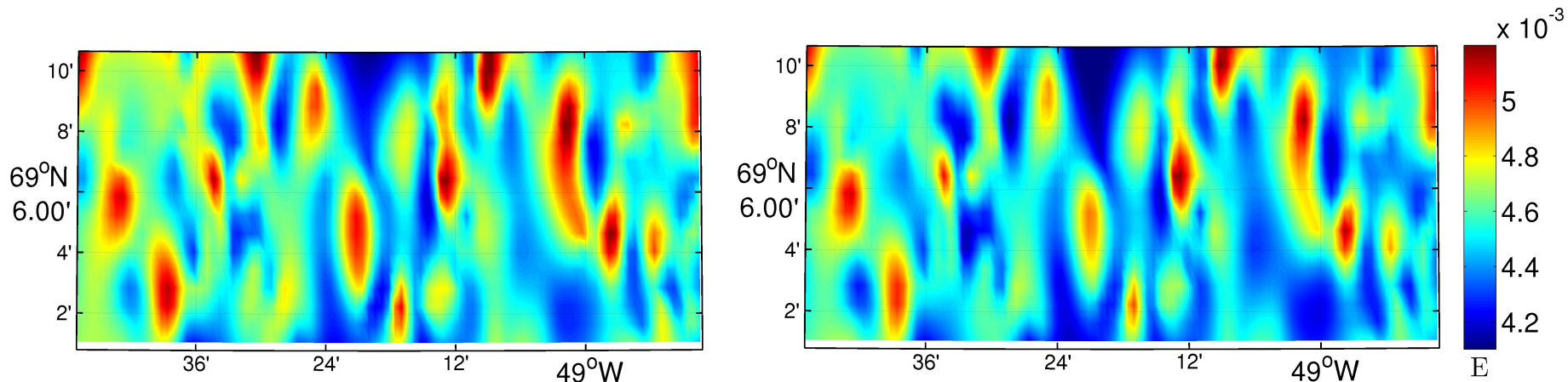
Gravity change from height change by TC



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



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



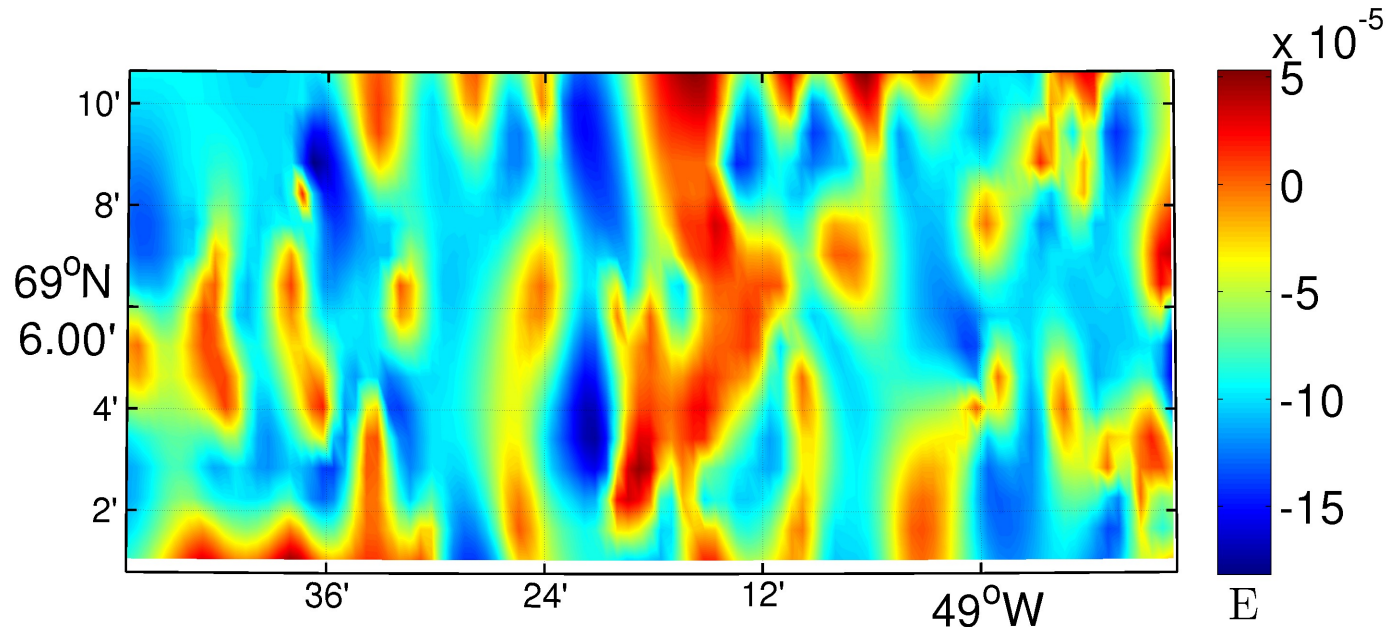
Tzz for 08.2007.

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  $T_{zz}$  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 observe this small signal (4 years of observations to be available at the end of 2013)

