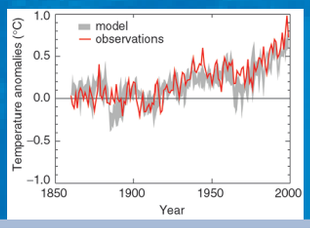
Using GPS and Absolute Gravity to Investigate Ice Mass Change in Greenland

T.M. van Dam[1], O. Francis[2], J. Wahr[3] and K. Larson[3]

[1]European Center for Geodynamics and Seismology, Luxembourg
[2]University of Luxembourg
[3]University of Colorado Boulder, USA

Motivation: To try to understand the relationship between global climate warming, global sea level rise, and changes in the mass of the Greenland ice-sheet.



Global temperature anomalies indicate the Earth's climate is heating up.

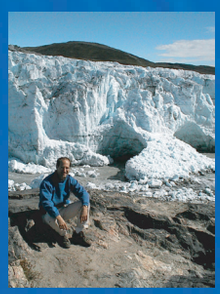
As a consequence of global warming, sea level is rising at a rate of ~ 2 mm/yr.

⇨ 25-50% of the sea level rise will be due to the thermal expansion of water

- and -

⇨ 45-65% melting glaciers, ice caps and ice sheets

We don't know if ice mass changes on Greenland are making sea level go up or

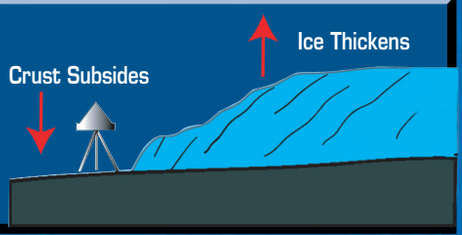


Prof. O. Francis in Greenland

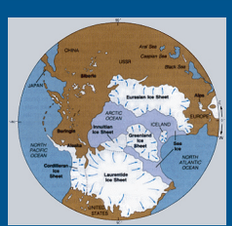
We use GPS and Absolute gravity to look at how the mass of the Greenland ice sheet is changing. But how does this work?

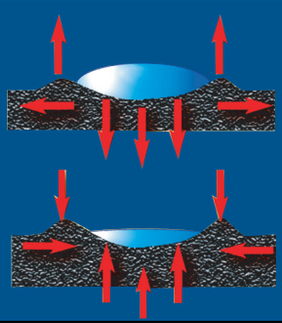
1. We know the Earth is elastic-this means that when we apply a load, like a change in ice mass, we can predict the deformation of the Earth's crust.
2. If we can predict the deformation from the load, then we can also do the reverse, i.e. measure the deformation using GPS or Gravity and estimate the load.

By measuring the deformation of the crust near the ice sheet using GPS, we can estimate the change in ice mass.

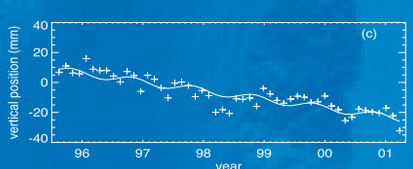


We have a problem, however. The crust in Greenland is moving due to present day changes in the ice load. But it is also deforming due to past changes in glaciation, the familiar post-glacial rebound, due to melting of the ice from the last glacial maximum of 50,000 years ago.





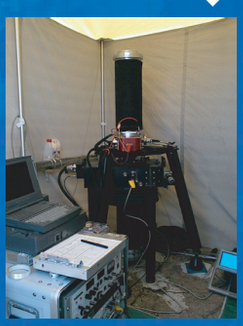
- under forces applied over geological time scales, the earth behaves as a fluid...it cannot sustain surface loads and flows in response
- 90,000 - 10,000 YBP ice sheets grew to maximum
- it took only 5000 years to melt -- and the earth is still responding
- post-glacial rebound or glacial isostatic adjustment

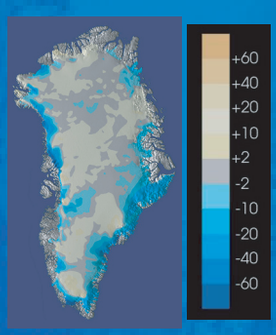


GPS data indicate that the site at Kangerlussuaq is going down, indicating that the ice is thickening in the southern third of Greenland. This conclusion is supported by results from NASA.

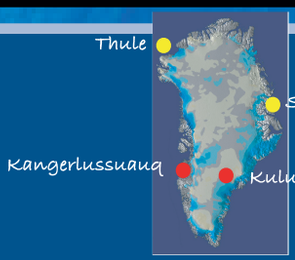
How can we discriminate between crustal motions due to present day changes in ice and crustal motions due to post glacial rebound?
We separate the deformations due to present day ice mass change from the post-glacial rebound signal by taking both GPS and Absolute gravity observations.

Absolute Gravimeter in Greenland: Note that the instrument is in a tent and is sitting directly on bedrock!





mm thinning (negative numbers indicate thickening)



Red dots indicate location of ECGS GPS Gravity observations.

Experiment details:

1995 - Establish continuous GPS site on the West coast of Greenland in Kangerlussuaq
Begin Absolute gravity Survey

1996 - Establish continuous GPS site on the East coast at Kulusuk
Begin Absolute gravity survey

Thule is a continuous site established an maintained by JPL in support of their ICESat satellite; Scoresbysund is a site established by the Danish Cadastre to maintain their geodetic network. A second Cadastre site has been established in Nuuk in the South of Greenland (not shown).

Greenland image obtained from the UNAVCO Inc.Web page (UNAVCO facility, Boulder, CO., USA) using their Jules Verne Voyager Map Tool. The map was made using GMT (Wessel, P. and W.H.F. Smith, New, improved version of Generic Mapping Tools released, EOS Trans. Amer. Geophys. U., 79, pp. 579, 1998) system calls.