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Crustal thickness estimation and interpretation in Greenland from space gravity data.

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1 Abstract

Uses of recent gravity data, from Gravity Recovery And Climate Experiment (GRACE) and Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellites, are an effective solution to obtain stable data over Greenland.
EGM2008 gravity model (Pavlis et al., 2008 and 2012) was used, as well as topography and ice thickness data from BedMachine v4 (Morlighem et al., 2017), to reverse the complete Bouguer anomaly and obtain the thickness of the Greenlandic crust.
Our results indicate an average thickness ranging between 45 and 47 ±4.5 km, with thin zones of 40 to 44 ±4.5 km and thick structures varying from 48 ±4.5 km up to 57 ±4.5 km. Our results are consistent with other studies albeit locally different on the coasts.
A geological interpretation of our results has been done and infer the presence of the Archean craton, the Paleoproterozoic domain, the Caledonian and Ellesmerian orogens, as well as another structure that could correspond to Paleo-Neoproterozoic basins.

2 Method

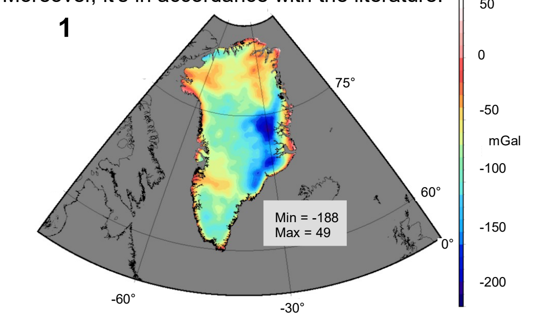
Topography and ice thickness came from the model BedMachine v4.
Free air anomaly model, EGM2008, was corrected to obtain the complete Bouguer anomaly over Greenland and its surroundings, thanks to the Parker method (Parker, 1972).

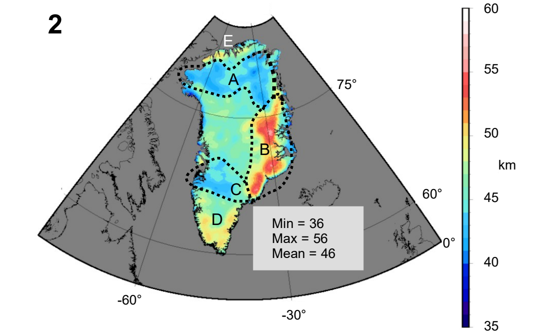
To reverse the complete Bouguer anomaly, we used the Matlab script 3DINVER.m from Gómez-Ortiz and Agarwal, 2005, which use the algorithm of Parker-Oldenburg.

The reference depth was chosen to be 38 km and we have tested two values of crustal density, 2670 and 2900 kg/m³, considered has the limits.

3 Crustal Thickness

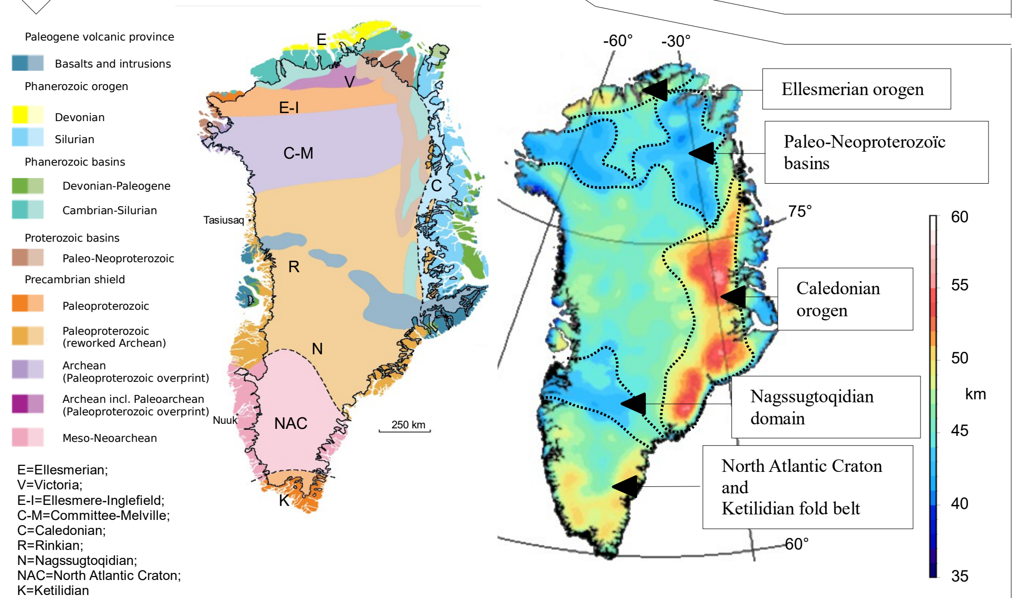
Underneath are shown the complete Bouguer anomaly (1) and crustal thickness (2) obtained using the fixed density of 2900 kg/m³.
2900 kg/m3 is the more realistic value for the rocs on zone B, a zone more sensitive to change in density. Moreover, it's in accordance with the literature.





Zones D, B and E have a higher thickness, whereas A and C are zones less thick than the average value of 46 ±4.5km.

4 Geological Interpretation



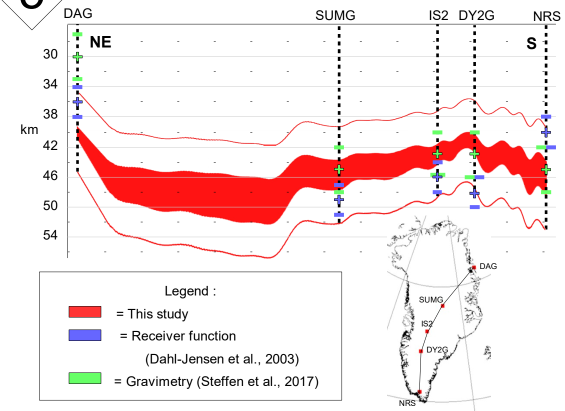
On the left side is the simplified geological map created by Dawes in 2009, and on the right side is the interpreted thickness resulting from this study, same as figure B.

Here the variations of thickness correlate well with Dawes in 2009. The North Atlantic Craton and the Ketilidian fold belt contrast with the less thick Nagssugtoqidian domain up north of them.

Compared to the geological map, the extent of the Nagssugtoqidian domain is narrower in our results. The Caledonian orogen is more south and inland than what Dawes has suggested in 2009. The map also suggests that basalt provinces cross Greenland east to west, but we can't confirm that assumption.

Finally, the two zones of thinner crust in the north could correspond to two Paleo-Neoproterozoïc basins. The hypothesis of straitgh lines for the zonations done in the north part of Greenland by Dawes cannot describe our results. Thus we propose that the two basins zones (N and NW) in brown could extend their reach under all the ice.

5 Discussion and Conclusion



This figure represents a Moho depth profile done between 5 stations, from DAG, on the NE coast, to NRS, at the southern tip. The boundaries of the red domain are computed with densities of 2670 kg/m³ (lower depth boundary) and 2900 kg/m³ (higher boundary), as well as the uncertainty (±4.5km).
Results from Dahl-Jensen et al., in 2003, using the receiver function method, and from Steffen et al., in 2017, doing, like us, a gravimetric inversion, are compared for those five stations.

Earlier values from gravimetry are concordant with this study for 4 stations, whereas values from Dahl-Jensen et al., are less close to us but in our uncertainty nonetheless. Station DAG shows a significant variation between us and Steffen et al. A part of this difference comes from the sedimentary structures present in the ocean. We didn't account for them in our method and it was calculated to have influence only on the coastline (1km for DAG).
Densities are of greater importance between DAG and SUMG, where the Caledonian orogen was determined to be (4-Geological Interpretation).

Conclusion

Using spatial gravimetry data is a great way to improve our geological understanding of what's under the ice. Even if the spatial resolution is not sufficient if we only use satellite data, EGM2008 which also combines ground and airborne, add more structural information than what was known before. Nonetheless, seismic results are somewhat different from ours, thus, to improve the precision and limit the range of our parameters, we hope that more studies using seismic, magnetism and ground geology take place.

6 References

An article for this study is currently being written.

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