French contribution to polar gravimetry

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Abstract

Four campaigns of absolute gravity (AG) measurements were conducted with FG5 and FG5-X absolute gravimeters in the region of Ross Sea and Terra Nova Bay in Antarctica in 2009, 2011, 2015 and 2018. The campaigns resulted from collaborations between French, Finnish, Italian, New Zealand and US agencies and institutes, the 2009, 2011 and 2015 campaigns having been supported by the international Polar Earth Observing Network (POLENET) program. Moreover, absolute gravity was also measured in Adélie Land in 2000, 2006 and 2019. We show the gravity variations at various stations, taking also into account AG measurements previously made in the 1990s. We also show the two AG measurement campaigns made in the french southern lands and the one made in Arctic, at Ny-Alesund, Svalbard.

Goals

Gravity depends on the distribution of the masses inside the Earth, which varies with time. AG measurements are necessary to:

- build models of the geoid
- study the long-term gravity variations, which are mainly caused by the post-glacial rebound and present-day ice melting
- discriminate between the different observations provided by space gravimetry.

They are complementary to precise positioning observations to constrain both the ice-mass variations over the polar regions and the post-glacial rebound.

Sites

AG sites we occupied at least once in 2009, 2011, 2015 or 2018 are located at McMurdo Station (McM, station THIEL), Scott Base (SB, station SBG-1), Cape Roberts (CR, station ROB4) and Mario Zucchelli Station (MZS, stations IAGS and TNB AB) in the region of Ross Sea and Terra Nova Bay. In 2000, 2006 and 2019 we also performed ground gravity measurements at Dumont d'Urville Station (DdU) in Adélie Land. In the french southern lands (Amsterdam, Crozet and Kerguelen) AG sites were occupied twice, in 2003 and 2005. At Ny-Alesund, 13 AG measurements were made, 7 using french FG5-X.

Ground gravity measurements

- The ground gravity variation δg is related to the space gravity variation Δg by $\delta g = \Delta g + \mathbf{u} \cdot \nabla g$, where $\mathbf{u}$ is the displacement of the ground and ∇g is the gradient of the static average gravity field.
- The ground displacement $\mathbf{u}$ can be measured by precise geodetic positioning techniques, such as GPS.
- The ratio $\delta g / \delta u$ is approx. 0.15-0.20 µGal/mm for the viscoelastic post-glacial rebound subsequent to the last deglaciation that occurred 20 000-10 000 years ago.
- The ratio $\delta g / \delta u$ is approx. 0.26 µGal/mm for the elastic deformation that accompanies the present-day ice melting.

Conclusions & Perspectives

Over Ross Sea, Terra Nova Bay and Adélie Land, as well as at Ny-Alesund in the Arctic, small gravity variations observed between over the last 20 to 30 years both on the ground and from space are of order of a few µGal/yr. In Antarctica, the 24-year trend can be a small gravity decrease or a small gravity increase. It requires a long-term monitoring for an accurate determination. In Ny-Alesund the rapid decrease of the gravity is directly due to past and present-day ice mass change and requires a regular monitoring. The next campaign is planed for 2021.

In the french southern lands, the 2020 campaign will provide a 16-year trend.

a GRACE : Gravity Recovery And Climate Experiment
b GRGS : Groupe de Recherche de Géodésie Spatiale

Unit : 1 µGal = 10^{-8} m/s²

Acknowledgment
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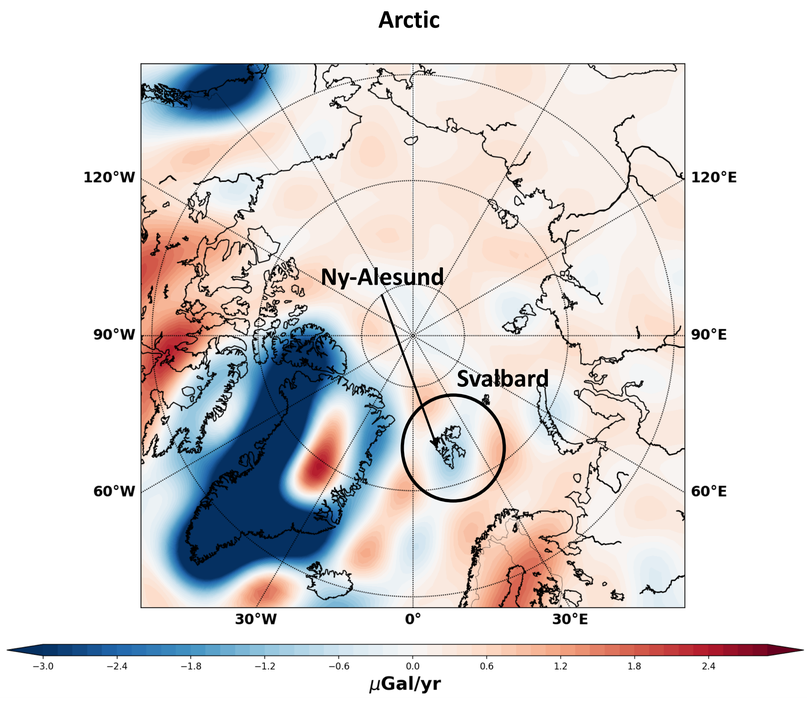
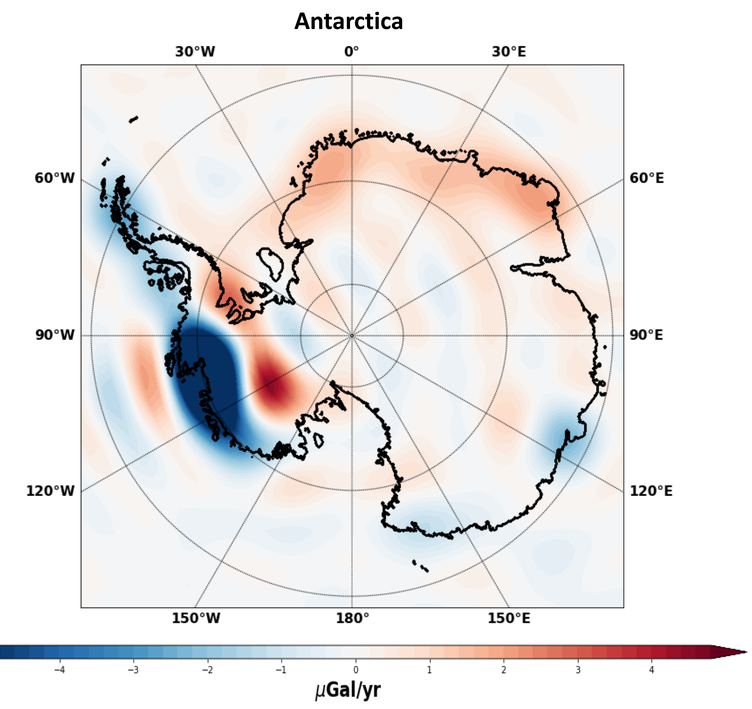
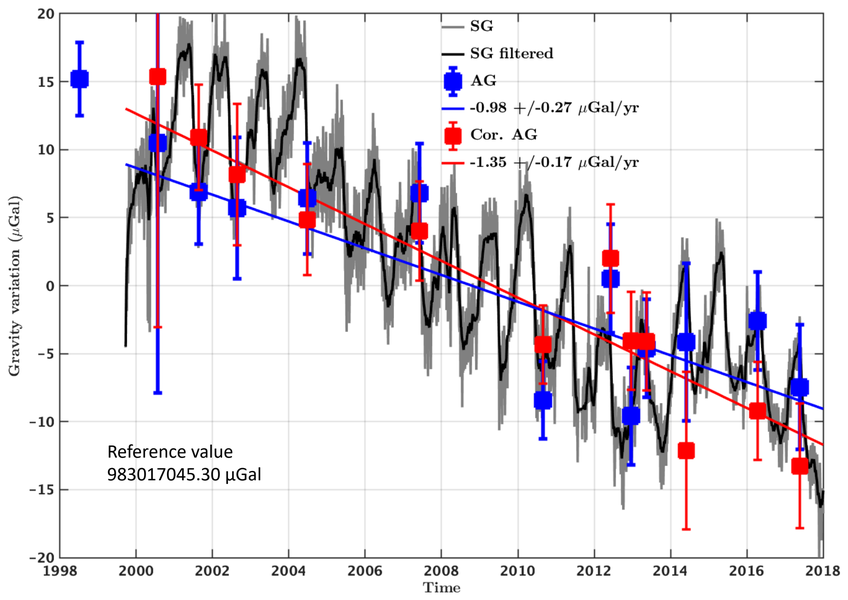
Gravity variations estimated from GRACE[a] (GRGS[b] RL4v1) between 2002 and 2016

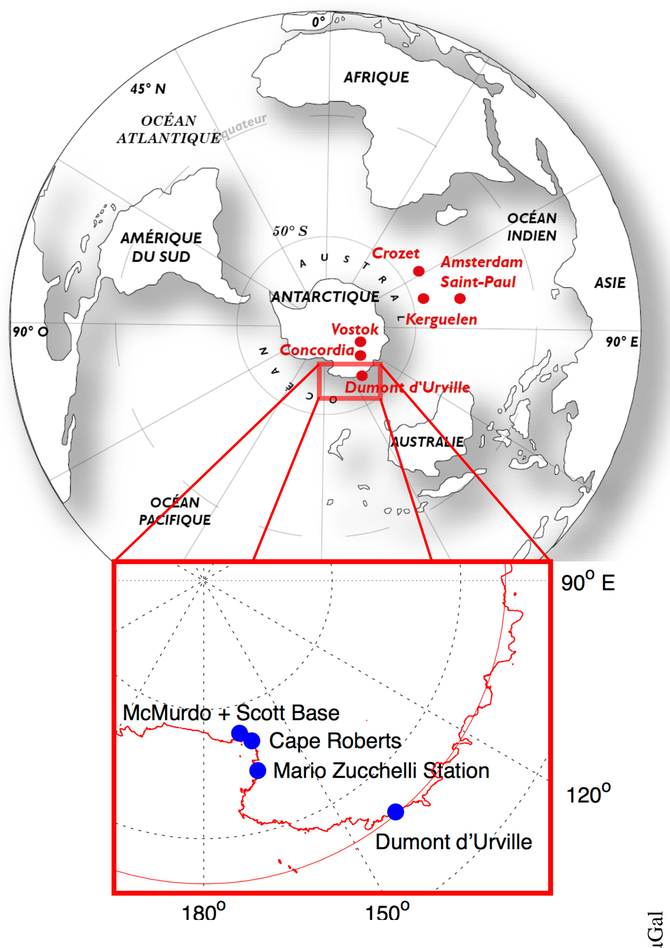


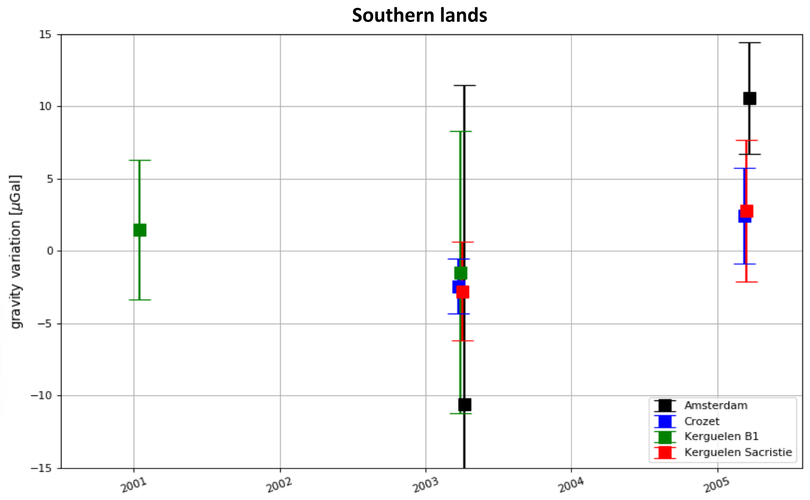


Gravity variations measured at Ny-Alesund, Svalbard



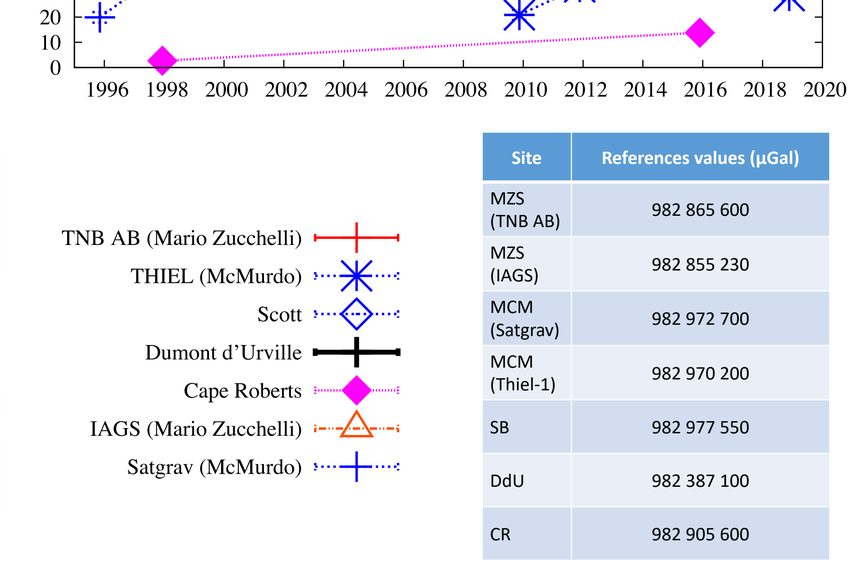
Gravity variations measured in Antarctica and the french southern lands





Site	References values (µGal)
Amsterdam	980 092 592.31
Crozet	980 964 480.27
Kerguelen B1	981 061 035.53
Kerguelen Sacristie	981 059 352.02

Dumont D'Urville site



Site	References values (µGal)
MZS (TNB AB)	982 865 600
MZS (IAGS)	982 855 230
MCM (Satgrav)	982 972 700
MCM (Thiel-1)	982 970 200
SB	982 977 550
DdU	982 387 100
CR	982 905 600