Evidence for new class of mantle upwellings from dynamic models

Sonja Spasojević[1] (sonja@gps.caltech.edu), Michael Gurnis[1] and Rupert Sutherland[2]

[1] California Institute of Technology, USA; [2] GNS Science, New Zealand

Forward models of New Zealand- Antarctica conjugate margins since 80 Ma

In forward models of Antarctica-New Zealand (ANT-NZ), anomalous geophysical observations are consistent with upwellings at mid-to-upper mantle depths above a lower-mantle anomaly linked to Gondwana subduction. Modeled upwellings in ANT-NZ are unusual in that they are above a subducted slab, possibly suggesting that significant hydration and/or melting occurs above subducting slab below 660 km. The inferred relative viscosity ratio between lower and upper mantle from ANT-NZ models is relatively high and could be related to extensive pileups of cold (more dense and viscous) slabs in lower 1000 km of the mantle regionally.

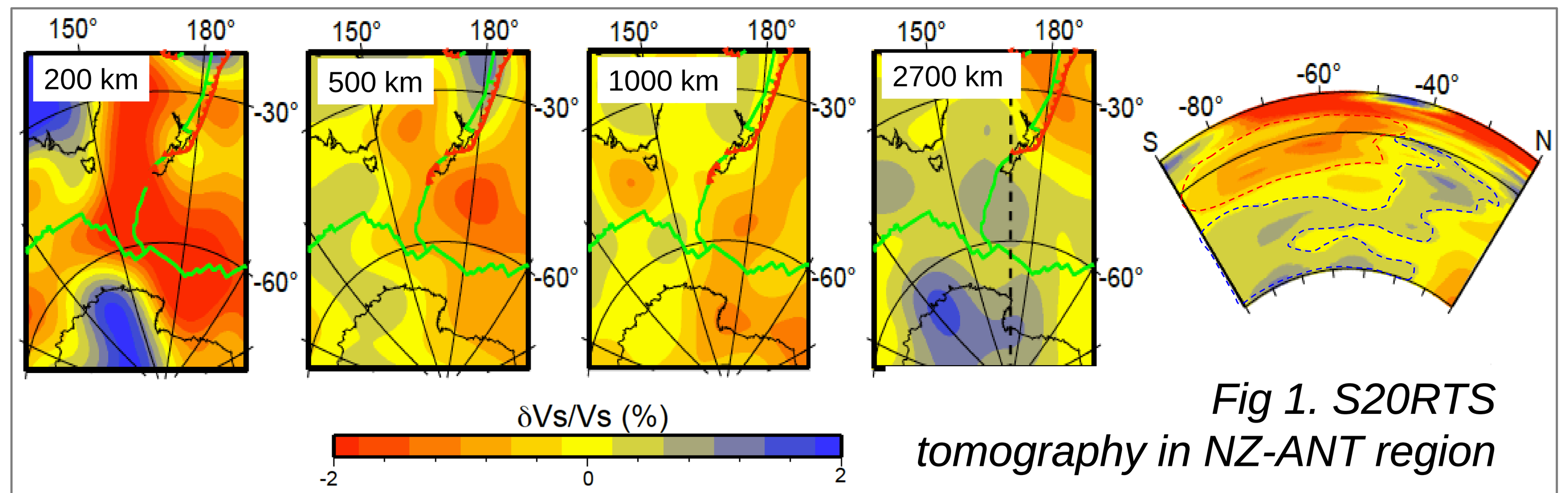

Fig 1. S20RTS tomography in NZ-ANT region

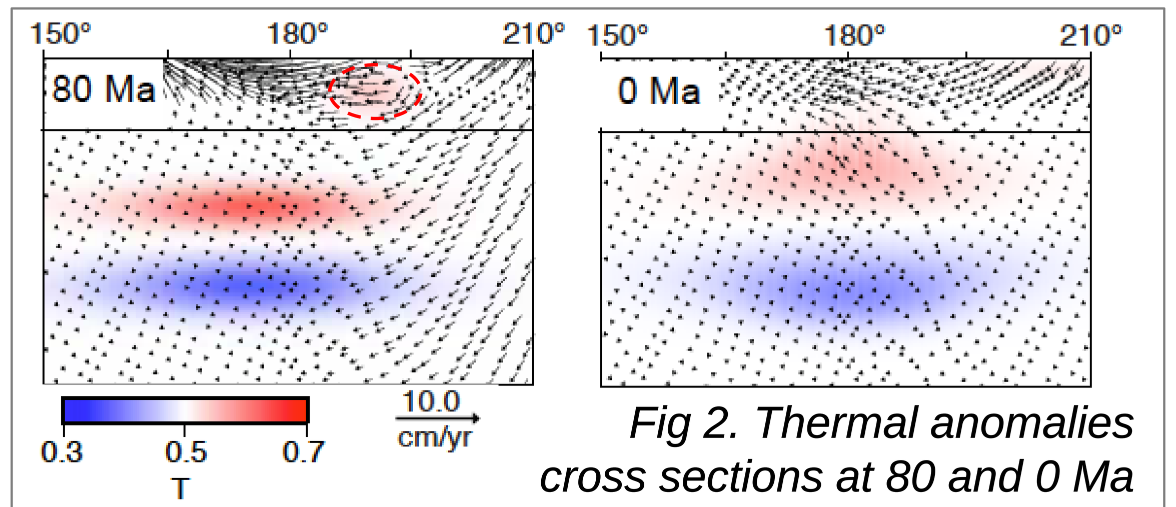

Fig 2. Thermal anomalies cross sections at 80 and 0 Ma

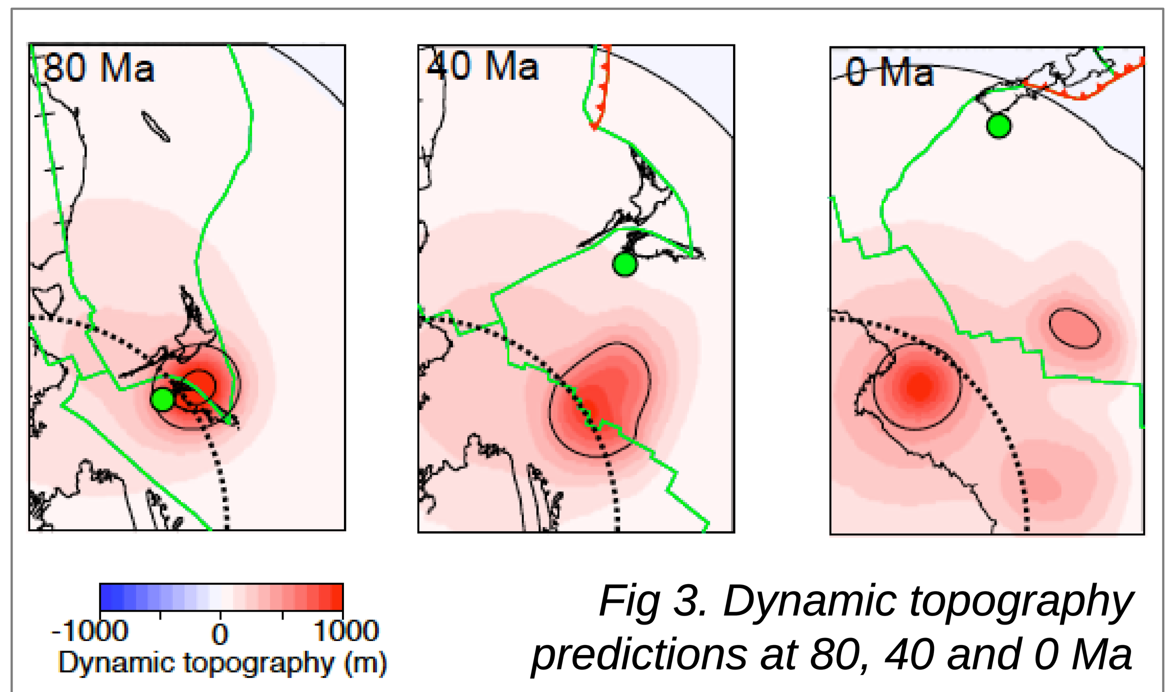

Fig 3. Dynamic topography predictions at 80, 40 and 0 Ma

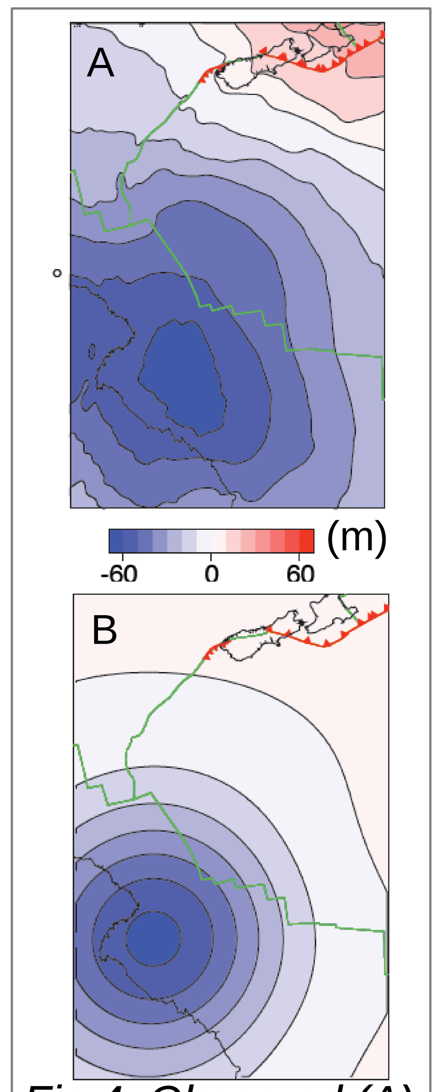

Fig 4. Observed (A) and predicted (B) geoid

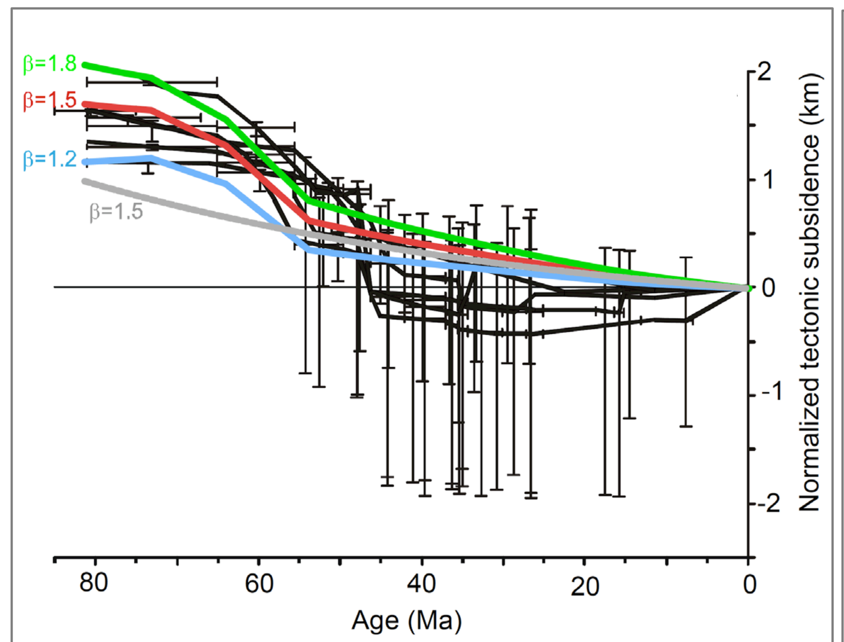

Fig 5. Subsidence of Campbell plateau

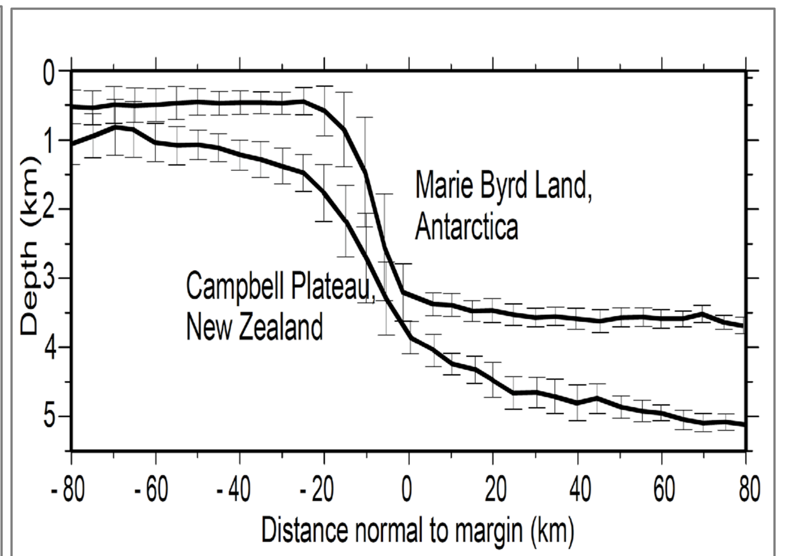

Fig 6. New Zealand- Antarctica margins bathymetry

Summary

We develop two sets of mantle convection models with the goal to investigate possible association of the regions of geoid minima with mantle upwellings. TIme-dependent forward models of New Zealand- Antarctica conjugate margins show that anomalous observations of residual bathymetry, tectonic subsidence and geoid can be explained by an evolving mid-to-upper mantle upwellings located in the Ross Sea region. We investigate geoid lows in instantaneous dynamic models and we find that the geoid minima are globally associated with mantle upwellings located in depths up to 1000 km.

We suggest that the modeled mid-to-upper mantle upwellings are genetically associated with the subducted Mezosoic slabs that are now located in the lower mantle. We propose that these upwellings represent a new mode of upwellings that has not been noted earlier.

Seismic tomographic evidence

We find that the geoid lows are correlated with both high velocity anomalies near the base of the mantle and low velocity anomalies in the mid-to-upper mantle in the same regions. These low-seismic-velocity anomalies are found at depths of up to 1000 km and have absolute amplitudes that are at least as large as the deeper high-velocity anomalies. We speculate that these low-seismic-velocity anomalies represent upwellings that are well defined in the Ross Sea, northeast Pacific and west Atlantic, and poorly defined in the Indian ocean.

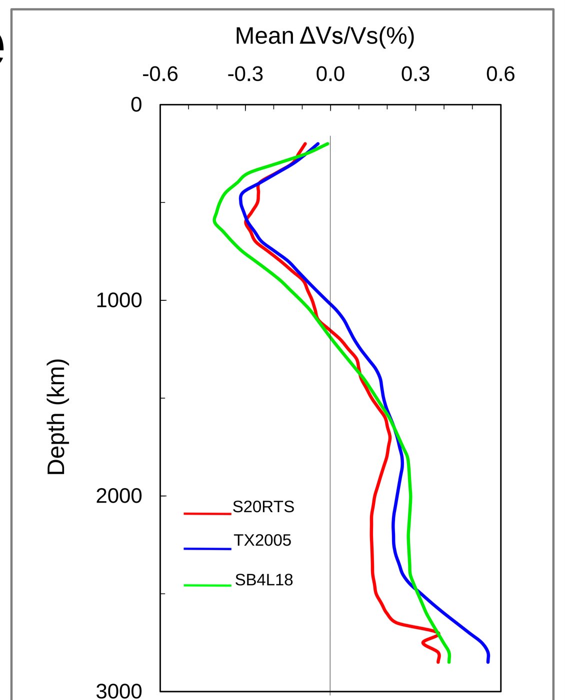

Fig 9. Mean tomography value in zones of geoid low

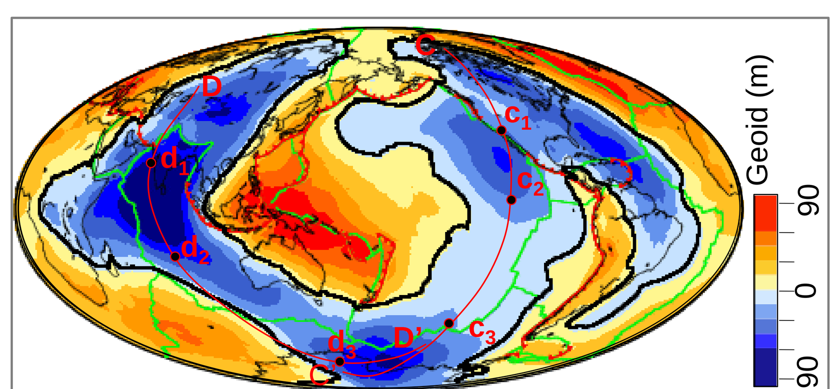

Fig 7. Observed geoid

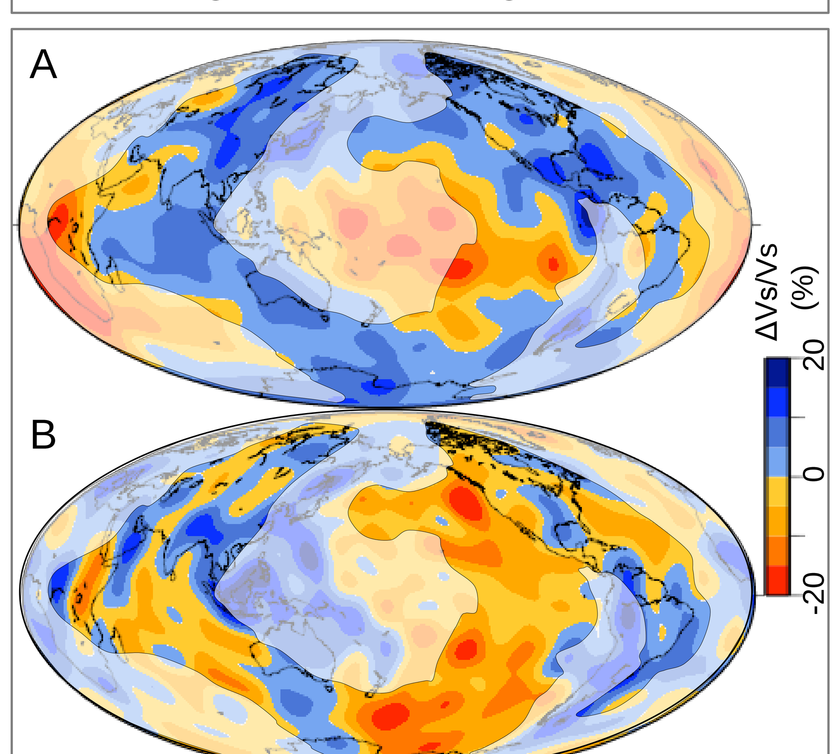

Fig 8. Stacked topography in 2000-2890 km (A) and 300-1000 km (B) depth

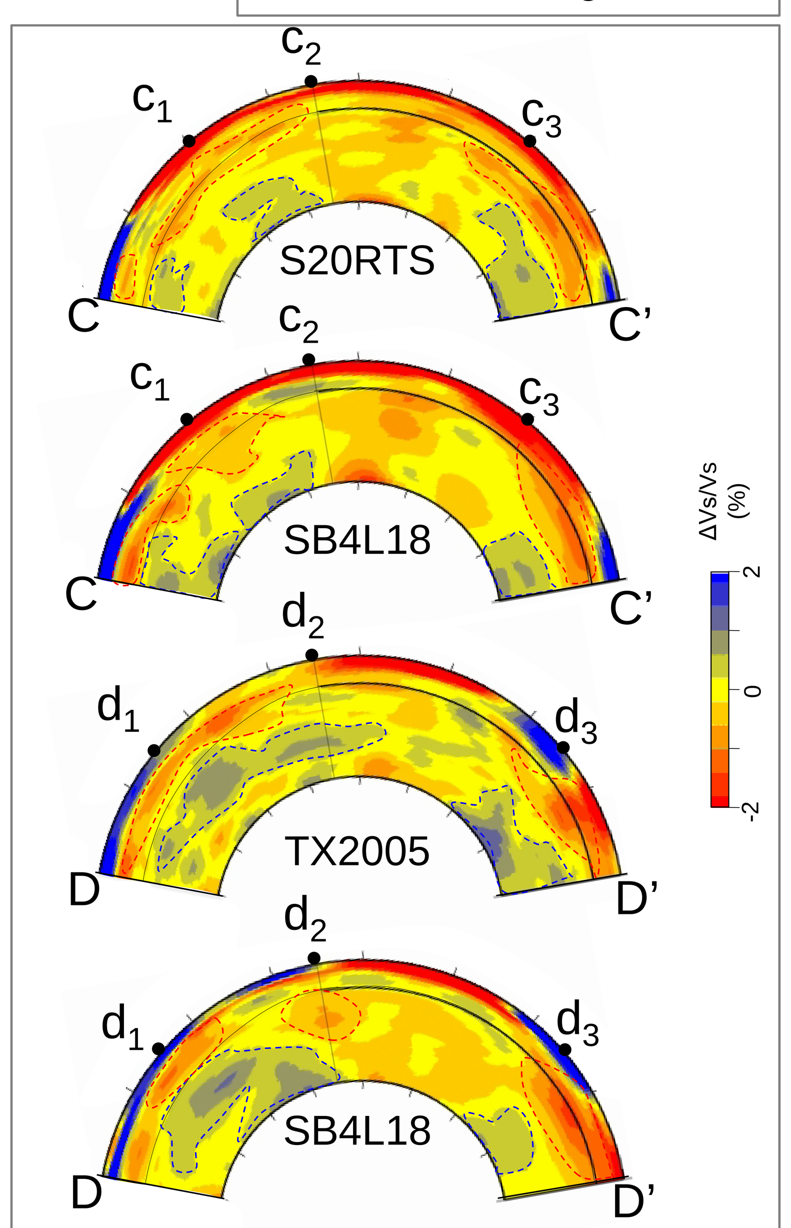

Fig 10. Tomography cross-sections in zones of geoid minima

Global instantaneous models and prediction of geoid lows

We develop global instantaneous models of mantle flow with the density field constrained by dynamic topography. These models demonstrate that mid-to-upper mantle upwellings have to be positioned above the inferred positions of ancient subducted slabs to reproduce the geoid minima in the Ross Sea, northeast Pacific, west Atlantic and Indian Ocean. We find that the high-density lower mantle slab graveyards reproduce the long-wavelength geoid trough, while upwellings shallower than 1000 km depth cause discrete lows within the larger trough. We suggest these upwellings are present globally and are probably caused by buoyant hydrated mantle that was created by processes around and above subducted slabs.

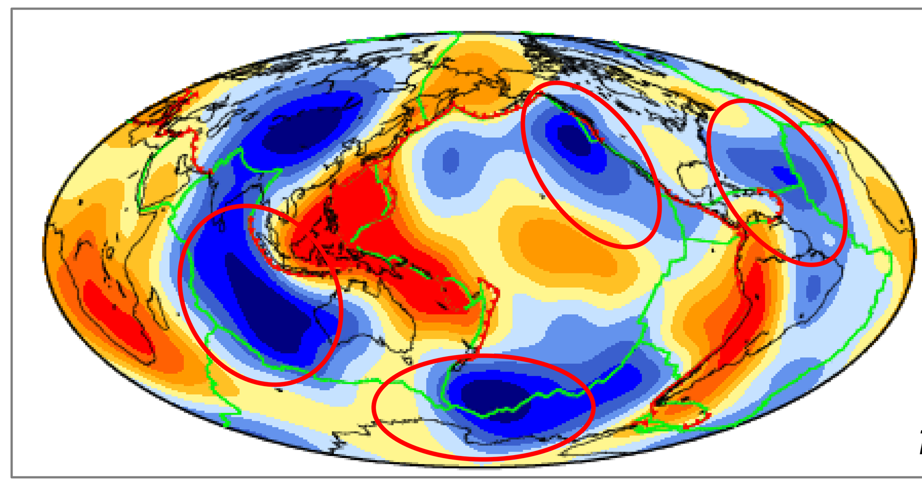

Fig 11. Predicted geoid with red circles indicating four regions of geoid minima

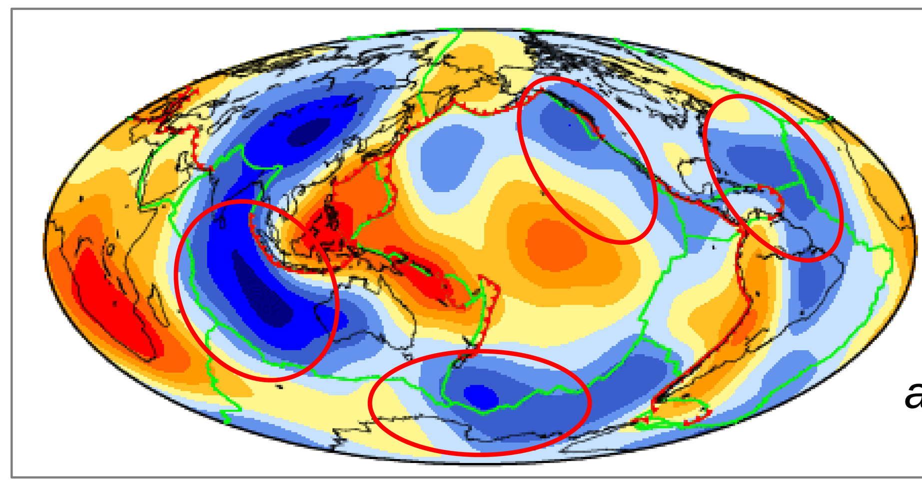

Fig 12. Geoid predictions with upwellings removed in upper 660 km of mantle (Note significantly reduced amplitudes of predicted geoid minima)

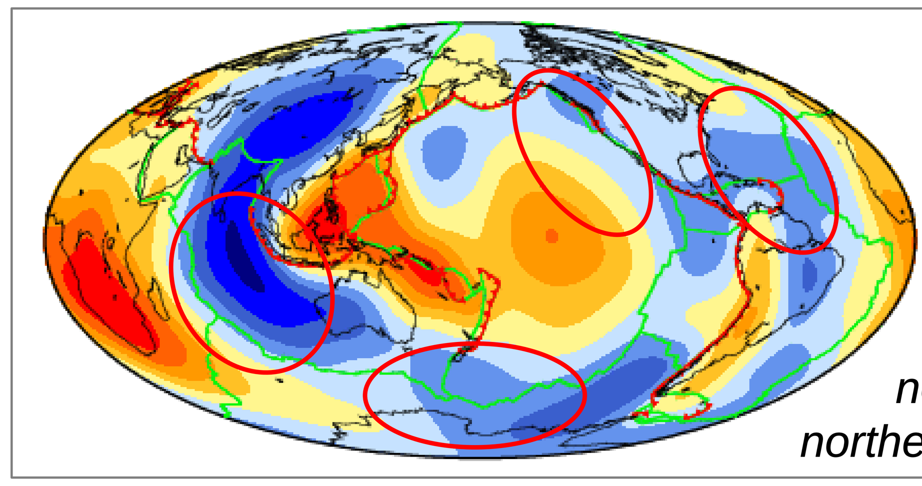

Fig 13. Geoid predictions with upwellings removed in upper 1000 km of mantle (Note that geoid minima are not predicted in the Ross Sea, northeast Pacific and west Atlantic)

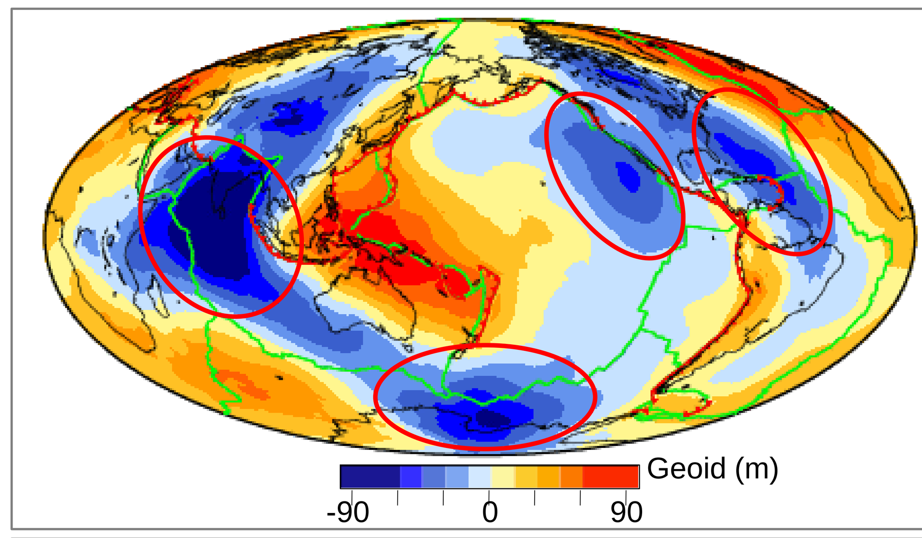

Fig 14. Observed geoid

Publications

1. Sutherland, R., S. Spasojevic, and M. Gurnis (2010), Mantle upwelling after Gondwana subduction death explains anomalous topography and subsidence histories of eastern New Zealand and West Antarctica, *Geology, 38 (2)*, 155-158.
2. Spasojevic, S., M. Gurnis, and R. Sutherland (2010), Inferring mantle properties with an evolving dynamic model of the Antarctica-New Zealand region from the Late Cretaceous, *JGR, 115,* B05402.
3. Spasojevic, S., M. Gurnis, and R. Sutherland (2010), Mantle upwellings above slab graveyards linked to the global geoid lows, *Nature Geoscience*, *3*, 435-438.