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Reducing Uncertainty in Upper Mantle Rheology, Lithospheric Thickness and Geothermal Heat Flow Using a Bayesian Inverse Framework to Calibrate Experimental Parameterisations of Anelasticity

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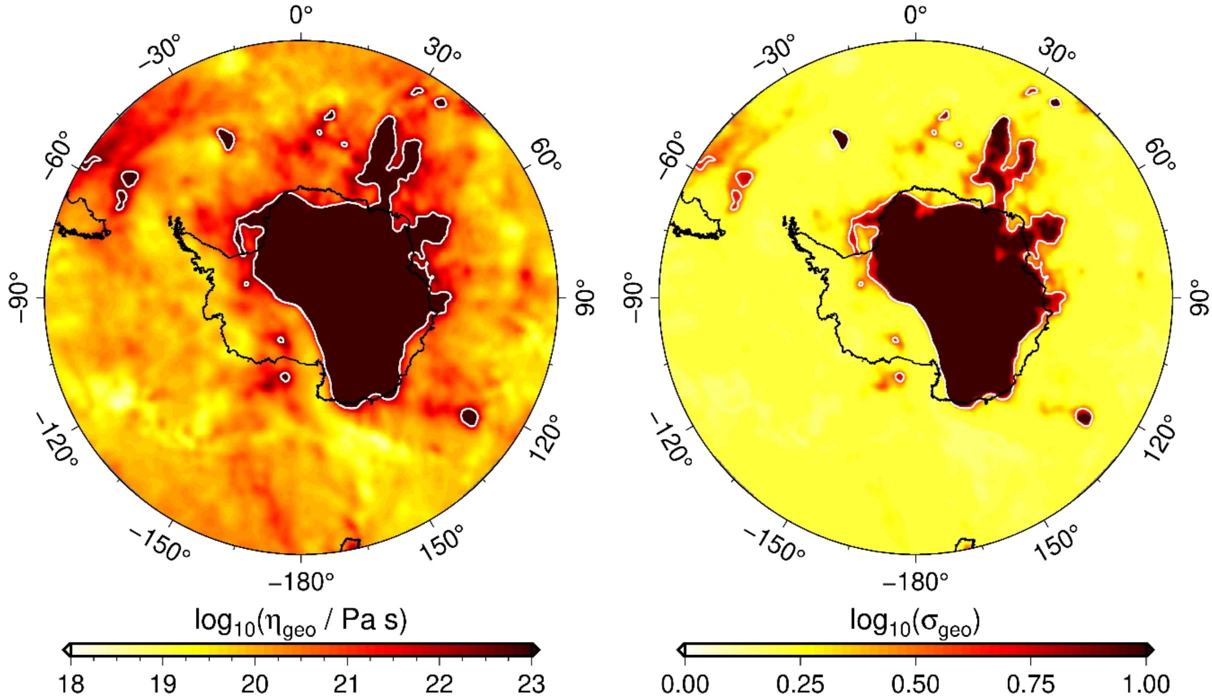
Uncertainty in present-day glacial isostatic adjustment (GIA) rates represent at least 44% of the total gravity-based ice mass balance signal over Antarctica. Meanwhile, physical couplings between solid Earth, sea level and ice dynamics enhance the dependency of the spatiotemporally varying GIA signal on 3D rheology. For example, the presence of low-viscosity mantle beneath melting marine-based ice sheet sectors such as the Amundsen Sea Embayment may delay or even prevent unstable grounding line retreat. Improved knowledge of upper mantle thermomechanical structure is therefore required to refine estimates of current and projected ice mass balance.

Here, we present a Bayesian inverse method for mapping shear wave velocities from high-resolution adjoint tomography into thermomechanical structure using a calibrated parameterisation of anelasticity at seismic frequency. We constrain the model using regional geophysical data sets containing information on upper mantle temperature, attenuation and viscosity structure. The Globally Adaptive Scaling Within Adaptive Metropolis (GASWAM) modification of the Metropolis-Hastings algorithm is utilised to allow efficient exploration of the multi-dimensional parameter space. Our treatment allows formal quantification of parameter covariances, and naturally permits us to propagate uncertainties in material parameters into uncertainty in thermomechanical structure.

We find that it is possible to improve agreement on steady state viscosity structure between tomographic models by approximately 30%, and reduce its uncertainty by an order of magnitude as compared to a forward-modelling approach. Direct access to temperature structure allows us to estimate lateral variations in lithospheric thickness, geothermal heat flow, and their associated uncertainties.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30°
60°
90°
120°
150°
−180°
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−90°
−60°
−30°
log10(ηgeo / Pa s)
18
19
20
21
22
23
log10(σgeo)
0.00
0.25
0.50
0.75
1.00