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Understanding glacial isostatic adjustment and ice mass change in Antarctica using integrated GPS and seismology observations

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The POLENET-ANET project is simultaneously resolving crustal motions, measured by GPS, and earth structure and rheological properties, mapped by seismology. Measured vertical and horizontal crustal motion patterns are not explained by extant glacial isostatic adjustment (GIA) models. These models have ice histories dominated by ice loss following the Last Glacial Maximum (LGM) and rely on 1D earth models, with rheological properties varying only radially. Seismological results from POLENET-ANET are revealing significant complexity in lateral variation in earth properties. Crustal thickness variations occur across the East-West Antarctic boundary and between crustal blocks within West Antarctica. Modeling of mantle viscosity based on shear wave velocities also resolves these tectonic boundaries, showing a sharp lateral gradient from high-to-low viscosity in the Ross Embayment, a much more gradual gradient in the Weddell Embayment, and very low viscosities below Marie Byrd Land and the Amundsen Sea Embayment (ASE). Vertical and horizontal bedrock crustal motion velocity magnitudes, directions and patterns correlate spatially, in many aspects, with earth property variations mapped by seismology.

Along the East-West Antarctic boundary in the Ross Embayment, GIA-induced horizontal crustal motions are toward, rather than away from, the principal ice load center, correlating spatially with the strong lateral gradient in crustal thickness and mantle viscosity. In the Weddell Embayment region, where crustal thickness is intermediate between East and West Antarctica and mantle viscosity values are moderate, crustal motions show the best match with predictions of GIA models. Within the ASE, extremely high upward velocities are flanked by subsiding regions – neither predicted by GIA models. Given the thin crust and low mantle viscosity, it is likely that this is not an LGM signal, which would have already relaxed, and uplift due to the elastic response to modern ice mass change clearly is important, but rapid GIA-induced uplift measured in the Amundsen Embayment may also record a viscoelastic response to ice loss on decadal-centennial time scales. Our integrated observations show that lateral variations in earth properties fundamentally influence the isostatic response to ice mass changes in Antarctica.