SERCE Key Papers

SERCE

SOLID EARTH RESPONSE AND INFLUENCE ON CRYOSPHERIC EVOLUTION

1. Whitehouse, P.L., Gomez, N., King, M.A., Wiens, D.A., 2019. Solid Earth change and the evolution of the Antarctic Ice Sheet. *Nat Commun* **10**, 1-14. https://doi.org/10.1038/s41467-018-08068-y

This invited review paper in Nature Communications summarises the current state-of-the-art in research associated with SERCE activities and interests and provides a review of future research priorities that will feed into future SCAR Scientific Research Program activities.

2. Nield, G.A., Barletta, V.R., Bordoni, A., King, M.A., Whitehouse, P.L., Clarke, P.J., Domack, E., Scambos, T.A., Berthier, E., 2014. Rapid bedrock uplift in the Antarctic Peninsula explained by viscoelastic response to recent ice unloading. *Earth Planet. Sci. Lett*. **397**, 32-41. https://doi.org/10.1016/j.epsl.2014.04.019

   Barletta, V.R., Bevis, M., Smith, B.E., Wilson, T., Brown, A., Bordoni, A., Willis, M., Khan, S.A., Rovira-Navarro, M., Dalziel, I., Smalley, R., Kendrick, E., Konfal, S., Caccamise, D.J., Aster, R.C., Nyblade, A., Wiens, D.A., 2018. Observed rapid bedrock uplift in Amundsen Sea Embayment promotes ice-sheet stability. *Science* **360**, 1335. https://doi.org/10.1126/science.aao1447

These studies document the use of GNSS observations to identify a viscous solid Earth response to contemporary ice loss. This was unexpected and is one strand of evidence that has been used to identify the presence of weak mantle material beneath West Antarctica.

3. Lloyd, A.J., Wiens, D.A., Zhu, H., Tromp, J., Nyblade, A.A., Aster, R.C., Hansen, S.E., Dalziel, I.W.D., Wilson, T.J., Ivins, E.R., O'Donnell, J.P., 2020. Seismic Structure of the Antarctic Upper Mantle Imaged with Adjoint Tomography. *J Geophys Res-Solid Earth* **125**, 33. https://doi.org/10.1029/2019JB017823

This study is one of many studies that have emerged during the lifetime of SERCE that document variations in mantle properties using seismic methods.

4. van der Wal, W., Whitehouse, P.L., Schrama, E.J.O., 2015. Effect of GIA models with 3D composite mantle viscosity on GRACE mass balance estimates for Antarctica. *Earth Planet. Sci. Lett*. **414**, 134-143. https://doi.org/10.1016/j.epsl.2015.01.001

Hay, C.C., Lau, H.C.P., Gomez, N., Austermann, J., Powell, E., Mitrovica, J.X., Latychev, K., Wiens, D.A., 2017. Sea-level fingerprints in a region of complex Earth structure: The case of WAIS. *J Climate* **30**, 1881-1892. https://doi.org/10.1175/JCLI-D-16-0388.1

Powell, E., Gomez, N., Hay, C., Latychev, K., Mitrovica, J.X., 2020. Viscous Effects in the Solid Earth Response to Modern Antarctic Ice Mass Flux: Implications for Geodetic Studies of WAIS Stability in a Warming World. *J Climate* **33**, 443-459. https://doi.org/10.1175/JCLI-D-19-0479.1

Building on evidence for spatial variations in mantle rheology beneath Antarctica, a suite of studies has sought to model the impact of these 3D variations when investigating the solid Earth response to ice sheet change.

5. Bradley, S.L., Hindmarsh, R.C.A., Whitehouse, P.L., Bentley, M.J., King, M.A., 2015. Low post-glacial rebound rates in the Weddell Sea due to Late Holocene ice-sheet readvance. *Earth Planet. Sci. Lett*. **413**, 79-89. https://doi.org/10.1016/j.epsl.2014.12.039

Kingslake, J., Scherer, R.P., Albrecht, T., Coenen, J., Powell, R.D., Reese, R., Stansell, N.D., Tulaczyk, S., Wearing, M.G., Whitehouse, P.L., 2018. Extensive retreat and re-advance of the West Antarctic Ice Sheet during the Holocene. *Nature* **558**, 430-434. https://doi.org/10.1038/s41586-018-0208-x

These studies document emerging evidence for ice sheet readvance during the Holocene. They hypothesise that this process was triggered by solid Earth rebound in response to earlier ice mass loss.

6. Gomez, N., Pollard, D., Mitrovica, J.X., 2013. A 3-D coupled ice sheet-sea level model applied to Antarctica through the last 40 ky. *Earth Planet. Sci. Lett*. **384**, 88-99. https://doi.org/10.1016/j.epsl.2013.09.042

Adhikari, S., Ivins, E.R., Larour, E., Seroussi, H., Morlighem, M., Nowicki, S., 2014. Future Antarctic bed topography and its implications for ice sheet dynamics. *Solid Earth* **5**, 569-584. https://doi.org/10.5194/se-5-569-2014

Konrad, H., Sasgen, I., Pollard, D., Klemann, V., 2015. Potential of the solid-Earth response for limiting long-term West Antarctic Ice Sheet retreat in a warming climate. *Earth Planet. Sci. Lett*. **432**, 254-264. https://doi.org/10.1016/j.epsl.2015.10.008

Gomez, N., Pollard, D., Holland, D., 2015. Sea-level feedback lowers projections of future Antarctic Ice-Sheet mass loss. *Nat Commun* **6**, 8798. https://doi.org/10.1038/ncomms9798

Pollard, D., Gomez, N., DeConto, R.M., 2017. Variations of the Antarctic Ice Sheet in a coupled ice sheet-Earth-sea level model: sensitivity to viscoelastic Earth properties. *Journal of Geophysical Research: Earth Surface* **122**, 2124-2138. https://doi.org/10.1002/2017JF004371

Larour, E., Seroussi, H., Adhikari, S., Ivins, E., Caron, L., Morlighem, M., Schlegel, N., 2019. Slowdown in Antarctic mass loss from solid Earth and sea-level feedbacks. *Science* **364**, 969
https://doi.org/10.1126/science.aav7908

The recognition that there are two-way feedbacks between solid Earth deformation and ice sheet dynamics has triggered a new area of research during the lifetime of SERCE. This research has revolved around the development of coupled ice sheet-solid Earth models.

7. Gomez, N., Latychev, K., Pollard, D., 2018. A coupled ice sheet-sea level model incorporating 3D Earth structure: Variations in Antarctica during the last deglacial retreat. *J Climate* **31**, 4041-4054.
https://doi.org/10.1175/JCLI-D-17-0352.1

The culmination of research into the effect of 3D mantle rheology and feedbacks between ice sheet dynamics and solid Earth deformation is this paper that documents a new model that accounts for both effects.

8. Shepherd, A., Ivins, E., Rignot, E., Smith, B., van den Broeke, M., Velicogna, I., Whitehouse, P., Briggs, K., Joughin, I., Krinner, G., Nowicki, S., Payne, T., Scambos, T., Schlegel, N., Geruo, A., Agosta, C., Ahlstrom, A., Babonis, G., Barletta, V., Blazquez, A., Bonin, J., Csatho, B., Cullather, R., Felikson, D., Fettweis, X., Forsberg, R., Gallee, H., Gardner, A., Gilbert, L., Groh, A., Gunter, B., Hanna, E., Harig, C., Helm, V., Horvath, A., Horwath, M., Khan, S., Kjeldsen, K.K., Konrad, H., Langen, P., Lecavalier, B., Loomis, B., Luthcke, S., McMillan, M., Melini, D., Mernild, S., Mohajerani, Y., Moore, P., Mouginot, J., Moyano, G., Muir, A., Nagler, T., Nield, G., Nilsson, J., Noel, B., Otosaka, I., Pattle, M.E., Peltier, W.R., Pie, N., Rietbroek, R., Rott, H., Sandberg-Sorensen, L., Sasgen, I., Save, H., Scheuchl, B., Schrama, E., Schroder, L., Seo, K.W., Simonsen, S., Slater, T., Spada, G., Sutterley, T., Talpe, M., Tarasov, L., van de Berg, W.J., van der Wal, W., van Wessem, M., Vishwakarma, B.D., Wiese, D., Wouters, B., Team, I., 2018. Mass balance of the Antarctic Ice Sheet from 1992 to 2017. *Nature* **558**, 219-222.
https://doi.org/10.1038/s41586-018-0179-y

Understanding the contemporary pattern of solid Earth deformation in response to past ice sheet change is a crucial step in being able to quantify present-day ice sheet change. Many SERCE-facing scientists were involved in this high-profile study.

9. Gunter, B.C., Didova, O., Riva, R.E.M., Ligtenberg, S.R.M., Lanaerts, J.T.M., King, M., van den Broeke, M.R., Urban, T., 2014. Empirical estimation of present-day Antarctic glacial isostatic adjustment and ice mass change. *The Cryosphere* **8**, 743-760.
https://doi.org/10.5194/tc-8-743-2014

Martin-Espanol, A., Zammit-Mangion, A., Clarke, P.J., Flament, T., Helm, V., King, M.A., Luthcke, S.B., Petrie, E., Remy, F., Schon, N., Wouters, B., Bamber, J.L., 2016. Spatial and temporal Antarctic Ice Sheet mass trends, glacio-isostatic adjustment, and surface processes from a joint inversion of satellite altimeter, gravity, and GPS data. *Journal of Geophysical Research: Earth Surface* **121**, 182-200.
https://doi.org/10.1002/2015JF003550

Sasgen, I., Martin-Espanol, A., Horvath, A., Klemann, V., Petrie, E.J., Wouters, B., Horwath, M., Pail, R., Bamber, J.L., Clarke, P.J., Konrad, H., Drinkwater, M.R., 2017. Joint inversion estimate of regional glacial isostatic adjustment in Antarctica considering a lateral varying Earth structure (ESA STSE Project REGINA). *Geophys J Int* **211**, 1534-1553
https://doi.org/10.1093/gji/ggx368

The contemporary pattern of solid Earth deformation in response to past ice sheet change can also be determined via the inversion of complementary satellite data sets.

10. Burton-Johnson, A., Dziadek, R., Martin, C., Halpin, J.A., Whitehouse, P.L., Ebbing, J., Martos, Y., Martin, A., Schroeder, D., Shen, W., Ritz, C., Goodge, J., Van Liefferinge, B., Pattyn, F., Reading, A., Ferraccioli, F., Sub-Group, a.t.S.G.H.F., 2020. Antarctic Geothermal Heat Flow: Future research directions. *SCAR/SERCE White Paper*.
https://www.scar.org/scar-library/reports-and-bulletins/scar-bulletins/5564-scar-bulletin-202/file/

An emerging strand of SERCE research is the role of geothermal heat flow (GHF) in controlling ice sheet dynamics. The distribution of GHF is poorly constrained – this recent SERCE White Paper documents our current state of knowledge on quantifying GHF across Antarctica.

11. Austermann, J., Pollard, D., Mitrovica, J.X., Moucha, R., Forte, A.M., DeConto, R.M., Rowley, D.B., Raymo, M.E., 2015. The impact of dynamic topography change on Antarctic ice sheet stability during the mid-Pliocene warm period. *Geology* **43**, 927-930.
https://doi.org/10.1130/G36988.1

On a longer timescale, dynamic topography change will impact ice sheet dynamics. This novel article documents the impact on ice sheet stability during a climatic warm period ~3 million years ago.

12. Aster, R.C., Winberry, J.P., 2017. Glacial seismology. *Rep Prog Phys* **80**, 39.
https://doi.org/10.1088/1361-6633/aa8473

Another emerging strand of SERCE research is the field of Glacial Seismology. This article documents the development and potential applications of this field.