My research agenda uses solid Earth deformation as a framework for understanding the intricate coupling between ice sheets, sea level and the landscape in the ice-age Earth system. During my dissertation research, I developed new geophysical methods to take advantage of a wide range of both traditional and non-traditional geologic sea-level records to revise models of both ice growth and decay, and to explore the implications for both global climate and ice sheet stability. I have demonstrated that records of past landscapes constitute a unique and powerful constraint on former ice sheets that has been significantly underappreciated. My future work will continue to focus on physical modeling of the interface between landscape evolution and the cryosphere through ice-age solid Earth deformation.

Insights into the last glacial cycle from solid Earth-ice sheet interactions

Taking full advantage of geological and geodetic measurements of sea level change requires a sophisticated understanding of solid Earth processes and structure. For example, the largest uncertainty in estimating excess ice volumes at the Last Glacial Maximum (LGM) is our incomplete knowledge of mantle viscoelastic structure. In addition, the error budget in estimates of recent Antarctic mass balance based on GRACE satellite gravity measurements is dominated by uncertainty in the rate of regional crustal uplift associated with ongoing glacial isostatic adjustment. Connecting climate and solid Earth research is a new frontier in Earth Sciences that holds the promise of resolving long-standing enigmas and contentious debates in both disciplines. My research lies at this interface, and focuses on leveraging solid Earth – ice sheet interactions through modeling of crustal deformation, mantle dynamics, and perturbations to both the Earth's rotation axis and gravitational field, in response to ice, water, and sediment load variations over the glacial cycle.

The history of past glacial cover is key to understanding the stability of ice sheets in today's changing climate. Prior to the Last Glacial Maximum (26 kyrs ago), during the glacial build-up phase, global ice volumes are particularly uncertain due to a sparsity of sea-level records. Indeed, evidence of past sea level has largely been destroyed or submerged by subsequent sea-level rise during the deglaciation. Furthermore, it is challenging to reconstruct individual ice sheets because an advancing ice sheet razes evidence of previous ice margins. Oxygen isotope ratios act as a proxy for global ice volume, though the required mapping between the two is uncertain at a level of tens of meters of global sea level, and these records have motivated the widely held view that ice ages are characterized by a slow glacial build-up phase followed by a rapid deglaciation.

My research challenges the assumption of a slow glaciation phase. I demonstrated that global ice volumes more than tripled in the ~15 kyrs leading into the Last Glacial Maximum through an analysis of Marine Isotope Stage (MIS) 3 sea-level markers in the Yellow River Delta (Pico et al., *QSR*, 2016). By extending the theory used in ice age sea-level models to account for sediment compaction in a gravitationally self-consistent manner, I corrected these markers for the effects of glacial isostatic adjustment, sediment loading, and sediment compaction. This research highlights the utility of using sedimentary core records to constrain under-sampled periods of the ice age, and provides a template for elucidating the details of the glacial phase to unprecedented accuracy.

In regions of high sedimentation, it is crucial to account for the impact of sediment loading and compaction on sea-level markers. In collaboration with Alan Mix, at Oregon State University, I am using this insight to model the impact of sediment loads sourced from rapidly-eroding regions of Alaska on the elevation of the Bering Strait on million-year timescales. The elevation history of the Strait has important implications for understanding changes in the Atlantic Meridional Overturning Circulation over the mid-Pleistocene transition. I have also investigated the impact of sedimentation on Last Interglacial (~122 ka) sea-level markers. In particular, I constructed a synthetic sedimentation history over the last glacial cycle by simulating delta deposition using a diffusive model and a migrating shoreline (Pico, *GJI,* 2019*)*. In future work, I aim to further extend the sea-level theory by accounting for loading self-gravitation in, and deformation of, lakes and restricted ocean basins.

As a next step in my doctoral research, I showed that the late growth of North American ice sheets can explain the rapid fall in global sea level leading into the Last Glacial Maximum. I investigated anomalously high MIS 3 sea-level records in North America (50-35 kyrs ago) and demonstrated that these sea-level records are dominated by crustal deformation induced by nearby ice loads, and suggest a late and substantial growth of the eastern sector of the Laurentide Ice Sheet. This result is consistent with non-glacial deposits dated to MIS 3 in this formerly glaciated region (Pico et al., *Nature Comm*., 2017; Pico et al., *QSR*, 2018; Dalton et al., *Geology,* 2019). Sea-level records along the formerly uplifted region surrounding the ice sheet, termed the peripheral bulge, provide an important and productive future direction for research aimed at constraining the history of ice cover during a time interval in which evidence from such regions was largely obliterated by an advancing ice sheet.

In another direction of research, I have collaborated with experts in numerical ice modeling on a study which found that simulations of North American ice growth using a reduced MIS 3 ice sheet result in rapid rates of ice accumulation leading into the Last Glacial Maximum (Pico et al., *QSR*, 2018). In future work of this type, my goal will be to explore how a reduced MIS 3 North American ice sheet revises our knowledge of contemporaneous atmospheric circulation across Laurentia, information that will deepen our understanding of the fundamental speed limits of ice growth and decay.

The timing of the last separation between the major North American ice sheets is critical to paleoclimate studies as well as to arguments that an ice-free corridor served as a path for early human migration. In a study accepted in *Science Advances*, I used glacial isostatic adjustment modeling, along with evidence of the enigmatic history of Bering Strait flooding, to fingerprint melting of the ice saddle between the Laurentide and Cordilleran Ice Sheet. While previous studies have suggested that melting of the ice saddle contributed significantly to Meltwater Pulse 1a (an event characterized by a sea level rise of 15-20 m globally in less than 300 yrs), I found that a dominant portion of this ice melted at a later time, from 13-11.5 kyrs ago. Melting of the ice saddle induces a regional sea-level fall at the Bering Strait, ~2000 km to the west, through a reduction of the gravitational attraction between the oceans and large continental ice sheets, which explains the observed two-phase flooding history of the strait (Pico et al., *in press, Science Advances*). The timing of this initial connection is key to accurately reconstructing past climate variability as submergence of the Bering Strait strongly modulates ocean circulation. Moreover, the melting of the ice saddle routes large volumes of freshwater directly to the Arctic, providing a trigger for the widely debated source of the Younger Dryas global cooling event (12.9-11.7 kyrs ago).

The timing of ice unloading during the last deglaciation directly controls bedrock topography underneath the receding ice sheet through crustal rebound. In collaboration with Alex Robel (Georgia Tech), I examined the influence of different deglacial histories of the North American ice saddle, connecting the Cordilleran Ice Sheet (CIS) and western Laurentide Ice Sheet (LIS), on the stability of the fast-flowing Amundsen Ice Stream, which was part of the Northwestern Laurentide Ice Sheet. These results suggest that short-lived changes in ice stream behavior may be used to reveal larger-scale and longer-duration ice sheet dynamics (Pico et al., *GRL,* 2019).

Solid Earth-landscape interactions improve ice sheet reconstructions

Long-term river evolution is controlled by external dynamics, such as regional tectonics, that shape the local topography crossed by the river. Yet on glacial timescales, rates of load-induced isostatic adjustment are comparable to fast tectonic uplift rates (~10 mm/yr), and thus reach a level sufficient to substantially influence river courses and drainage basins. My research has explored the extent to which rivers are influenced by the glacial isostatic adjustment process. Because rivers are sensitive to changes in slope, past landscapes can faithfully record surface deformation, thereby yielding insight into past ice loading. I exploit geologic records of rivers as a novel technique for inferring the history of glaciations by quantitatively connecting evidence of past river dynamics to numerical simulations of glacial isostatic adjustment.

A fast growing Laurentide Ice Sheet initiated uplift along the U.S. east coast at rates of 10 mm/yr as the solid Earth adjusted to an expanding ice load. In my doctoral work I defined a new direction of ice age research by coupling state-of-the-art models of landscape evolution and glacial isostatic adjustment. This work demonstrated that a late and rapid glaciation of the Laurentide Ice Sheet drove the eastward diversion (rerouting) of the Hudson River 30 kyrs ago inferred from the geologic record (Pico et al., *Geology*, 2018). Moreover, these simulations provide a unifying mechanism for explaining abrupt changes in river dynamics that took place across the U.S. mid-Atlantic in the Delaware, Susquehanna, and Potomac rivers (Pico et al., *EPSL*, 2019). In a similar vein, I am working with Paul Bierman at the University of Vermont, to investigate the rapid pulse of incision recorded in the Potomac at 30 kyrs ago, showing that uplift from glacial isostatic adjustment may be a viable mechanism for river channel lowering given that exposure ages on bedrock terraces are inconsistent with the common assumption that incision was caused by knickpoint retreat (Bierman et al., in prep).

In future work I will extend the methods I have developed to consider other rivers situated on the peripheral bulge of ice sheets, whose histories were potentially impacted by glacial isostatic adjustment. For example, I am interested in quantitatively testing the hypothesis that the Rhine-Meuse River in the Netherlands changed course in response to glacial isostatic adjustment during MIS 3. By coupling predictions of this adjustment based on different Scandinavian ice sheet growth histories with landscape evolution models that account for both bedrock and alluvial processes, I propose to refine our understanding of the MIS 3 Scandinavian ice sheet, and of how solid Earth dynamics can impact river dynamics hundreds of kilometers away from ice cover.

Finally, as an NSF Postdoctoral Scholar, in collaboration with Mike Lamb at Caltech and Alan Mix at Oregon State University, I will consider the impact of glacial isostatic adjustment on estimates of floodwater volumes and flood routing associated with Missoula megaflooding. Prior estimates of water volume and flow discharge during these glacial outburst flood events, which occurred from 22 to 14 kyrs ago, relied on slopes estimated from modern topography. However, over this time period, glacial isostatic adjustment caused crustal deformation at rates of ~10 mm/yr, orders of magnitude above regional uplift rates, and changed local slopes by ~30%. I intend to revisit estimates of total floodwater volume by using 2D hydraulic models to simulate Missoula flood routing on a topography corrected for glacial isostatic adjustment.

The Channeled Scablands are underlain by a complex lithospheric and mantle rheology, characterized by strong lateral variations. In modeling glacial isostatic adjustment in such regions, it is important to consider 3D mantle structure, rather than using a laterally-averaged 1D mantle viscosity profile. In collaboration with Konstantin Latychev (Harvard), I will construct and apply a finite-element 3D glacial isostatic adjustment model that adopts mantle viscosity and lithospheric structure inferred from a high-resolution regional North American tomography model. This research will explore the effect of 3D Earth structure on solid Earth deformation in response to the growth and melt of the Cordilleran Ice Sheet, with constraints provided by relative sea level records in the Pacific Northwest. In addition, the simulations will provide accurate predictions for crustal deformation in the Channeled Scablands region, with implications for the size and depth of Glacial Lake Missoula, as well as subsequent flood dynamics.

The projects described above span a range of topics united by using solid Earth deformation as a lens for understanding past changes on Earth's surface, including climate, ice sheets, and landscapes. Through my expertise in modeling glacial isostatic adjustment, I aim to target knowledge gaps at the interface between geodynamic processes and ice sheet evolution.

Gender in Geoscience

Seeking to better understand and address the persistent underrepresentation of women and minorities in the geosciences drove me to pursue research in gender studies, through a Ph.D. concentration in Women, Gender, and Sexuality Studies. In this stream of my research, I use quantitative and qualitative methods to document and analyze how social conventions and cultural practices affect the retention of women and underrepresented minorities in our field.

In one study, I investigated the representation of women as first authors, and found a large first-authorship gender gap. First authorship is an important step for academic advancement. I used webscraping-techniques to compile the names of first authors for the last five years (n = 32408) in 13 leading geoscience journals. I classified the likely gender associated with the name using a database of 216286 names globally, across 89 languages. While the representation of female first authors varies significantly by subfield (16% to 31%), I found that female first authors represent less than 25% of total first authors in the majority of journals analyzed (10/13), a result I presented at the AGU Fall Meeting 2018 and that is currently under review at *PLOS ONE*.

Broadly, I am interested in understanding the origins of dominant cultural norms in geoscience that continue to impact women and minority geoscientists. I am exploring how practices in 19th century American geology continue to shape cultural norms and training of geoscientists today. For example, in work that originated in a seminar paper, I researched the 1869 Powell Expedition to the Grand Canyon, a formative event in American geology. As I demonstrate, primary sources reveal how this expedition participated in scientific racism and helped to construct masculinist ideals and conventions in the discipline that remain powerful today (Pico, *Scientific American*, 2019; Pico, GSA Fall Meeting, 2019). In a paper under revision for publication, I focus on cultures around harassment during modern geoscience fieldwork. By teasing apart language and communication style used during geologic fieldwork, I identify how "field speech" reinforces cultures of masculinity embedded in the development of the academic discipline (Pico, AGU Fall Meeting, 2019).

My research in gender studies results from my desire to expand Earth Sciences to marginalized groups, both within the discipline and in the broader community. I view this work as complementary to my central research agenda in ice age Earth systems.

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