WAIS Workshop 2025 Agenda (all times PDT)
YMCA Camp Casey
Coupeville, WA USA

Tuesday, September 16

2:00 pm – 5:00 pm	Check in: Pick up badges, swag (check in Wednesday and Thursday will be available during breaks in the agenda)	TBD
5:00 pm – 5:30 pm	WAIS Workshop Steering Group Meeting: All are welcome to join to discuss the status and future of WAIS Workshops	TBD
6:00 pm – 8:00 pm	Icebreaker and pizza dinner	TBD

Wednesday, September 17 – All oral presentations in Auditorium A
Upload your Wednesday presentation slides by 7 am here.

Breakfast: 8:00 am – 9:00 am

Session 0	Opening Business	Presenter
9:00 am	Welcome to WAIS Workshop 2025 & Goals	WAIS Committee
9:10 am	Local Introduction	Knut Christianson

Session 1	Measuring and Modeling Marine Ice Sheets Across Timescales	Presenter
9:20 am	Antarctic Ice Mass Loss Since 2002 From Satellite Time Variable Gravity Missions	Isabella Velicogna
9:30 am	Ice-sheet mass balance from satellite altimetry-gravimetry fusion precisely quantifies atmospheric and dynamic signatures of change	Matthew Siegfried
9:40 am	West Antarctic elevation history as a constraint on ice-sheet model physics	Eric Steig
9:50 am	Investigating Seasonal Glacier Fluctuations in Northeast Greenland Using Physics-Informed Machine Learning	Claire Jensen
9:50 am	Investigating Seasonal Glacier Fluctuations in Northeast Greenland Using Physics-Informed Machine Learning	Jessica Badgeley
10:10 am	Discussion	All

Refreshment Break: 10:40 am – 10:50 am

Session 2	WAIS and the Solid Earth	Presenter
10:50 am	Geophysical instrumentation in Antarctica: What will be missing and what should be retained?	Terry Wilson
11:00 am	Interpreting GPS Measurements of Crustal Motion and GRACE Time Varying Gravity in West Antarctica Using GIA Models With 3D Mantle Viscosity	Shijie Zhong
11:10 am	The impact of regional-scale upper-mantle heterogeneity on glacial isostatic adjustment in West Antarctica	Erica Lucas

11:20 am	The control of glacial isostatic adjustment and grounding-zone-wedge sedimentation on the evolution of ice stream stability in the Ross Sea (West Antarctica) over the last deglaciation	Samuel Kodama
11:30 am	Discussion	All

Lunch: 12:00 pm – 1:00 pm

1:00 pm	One minute poster teaser pitches (upload your 1 slide here by 8:00 am	Poster Presenters

Session 3	**The risk and reward of WAIS Drilling Projects**	**Presenter**
1:30 pm	NSF Center for Oldest Ice Exploration: Recent results, future plans and thoughts for the broader community	Ed Brook
1:40 pm	On the Inaccessibility of US Subglacial Access Drills	Britney Schmidt
1:50 pm	Sensitivity of the West Antarctic Ice Sheet to 2° Celsius of Warming: The SWAIS2C project	Molly Patterson

Session 4	**Notes from the Underground**	**Presenter**
2:40 pm	Gleaning additional insight from the satellite record with observations of waves on glaciers	Max Filter
2:50 pm	Radar swath imaging: a panacea for mapping the ice-sheet bed?	Knut Christianson
3:00 pm	Deep Learning Insights into Geological and Glaciological Controls on Antarctic Basal Friction	Racheet Matai
3:10 pm	Constraining ice thickness and basal conditions in Antarctic grounding zones using satellite observations and viscous beam modelling	Bryony Freer
3:20 pm	Discussion	All

Refreshment break: 3:50 pm – 4:00 pm

Poster Session: 4:00 pm – 5:00 pm
Dinner: 5:00 pm – 6:00 pm
Post-dinner breakouts: 7:00 pm – 8:00 pm (locations TBD)

Thursday, September 18
Upload your Thursday presentation slides by 7 am here.

Breakfast: 8:00 am – 9:00 am

Session 5	**The Role of Pinning Points Through Time**	**Presenter**
9:00 am	Collapse of the Ross Bank Ice Rise	Philip Bart
9:10 am	SWAIS2C Geophysics: Understanding geologic controls on ice rise formation	Paul Winberry
9:20 am	Model experiments coupling grounding-zone sedimentation and ice dynamics: grounding zone wedges, retreat, and stability	John Erich Christian
9:30 am	Rapid small-scale fracturing at pinning points prime ice shelves for tabular calving events	Fiona Clerc
9:40 am	Discussion	All

Refreshment Break: 10:10 am – 10:20 am

Session 6	Connect Four: Connect Four: Ice, Ocean, Atmosphere, Rock	Presenter
10:10 am	Turbulence observations beneath the Fimbul Ice Shelf, through a hot-water-drilled borehole	Yixi Zheng
10:20 am	The Influence of Bed Topography on Water Column Mixing and Ice-Ocean Interactions at Erebus Glacier Tongue, Antarctica	Veronica Hegelein
10:30 am	Where the Ice Meets the Sea: Sub-Ice-Shelf Tides and Grounding Zones with ICESat-2	Tyler Sutterley
10:40 am	Stabilizing factors of Cook Ice Shelf and Cook West Glacier, East Antarctica	Susan Howard
10:50 am	Discussion	All

Session 7	WAIS in the Classroom	Presenter
11:10 am	The West Antarctic Ice Sheet in Undergraduate Curriculum	Knut Christianson
11:20 am	From Drill Site to Insight: Engaging Students and the Public with West Antarctic Ice Sheet Science through SWAIS2C Education and Outreach	Marlo Garnsworthy
11:30 am	CURE-ing the Cryosphere	Mickey MacKie
11:40 am	Discussion	All

Lunch: 12:20 pm – 1:00 pm

Session 8	Community Discussion	Presenter
1:00 pm	Advocating for the future of USAP and US Antarctic Research	All

Optional glacial geology excursion: 2:00 pm – 5:00 pm
Dinner: 5:00 pm – 6:00 pm
Poster Session with refreshments: 6:00 pm – 8:00 pm

(please break down your poster and easel after this session!)

Friday, September 19

Upload your Friday presentation slides by 7 am here.

Breakfast: 8:00 am – 9:00 am

Session 9	Subglacial Hydrology	Presenter
9:00 am	Uncovering Seasonal Subglacial Groundwater Dynamics in Antarctica using Geologically Constrained Modeling and Satellite Altimetry	Rohaiz Haris
9:10 am	Apparent post-drainage refilling of subglacial lake Cook-E2 explained by high-resolution ice-flow modeling	Ben Smith
9:20 am	Discussion	All

Refreshment Break: 9:40 am – 10:00 am

Session 10	WAIS and Marine Ice Sheets Across Timescales	Presenter
10:00 am	Early Pliocene Current Strength Variability off West Antarctica Based on a Particle Size Record from the Resolution Drift, Amundsen Sea	Monika Ghimire
10:10 am	West Antarctic Ice Sheet Instability during Pleistocene Interglacials: Insight from foraminifera and paleotemperature reconstructions	Imogen Browne
10:20 am	Bivalve genomes do not show evidence of a West Antarctic	Erik Tamre
11:30 am	Discussion	All

Session 11	Ice Dynamics across scales	Presenter
10:50 am	Development of MITgcm ECCO-downscaled Amundsen-Bellingshausen Sea regional simulation	Yoshi Nakayama
11:00 am	Surface Height Increases from Extreme Snowfall Events Obscure Dynamic Thinning Across Antarctica	Susheel Adusumilli
11:10 am	Piecing together the evolution of ice shelf rift mélange with multi-sensor satellite observations	Chancelor Roberts
11:20 am	Effect of the flow-law exponent on ice-stream sensitivity to melt	David Lilien
11:30 am	Discussion	All

11:50 am	Wrap up	WAIS Workshop Committee

Lunch: 12:00 pm to 1:00 pm

Afternoon Workshops: 1:00 pm – 3:00ish pm

- *Open Polar Radar*
- *Introduction to NISAR*
- *Data & DAACs*

Posters

Title	Presenter
Debris-rich basal ice layers from Mercer Ice Stream, West Antarctica: Implications for ice stream basal dynamics	Tim Campbell
Probabilistic Inversion of Sub-ice-shelf Bathymetry around Antarctica	Michael Field
The Earth Dynamics Geodetic Explorer (EDGE) mission: A swath-imaging multifunction lidar for tracking the 3D structure of terrestrial ecosystems and surface topography of ice	Helen Fricker
The Sacred of the South: Public Engagement with West Antarctic Ice Sheet Science through Art	Marlo Garnsworthy
The impact of grounded icebergs on Prydz Bay, Antarctica	Alan Gaul
xOPR – Reproducible access to over 20 years and 2 petabytes of airborne measurements in Antarctica	Shane Grigsby
Random Forest Parameterization of Antarctic Subglacial Hydrology	Tim Hill
Geophysical Observations of Subglacial Hydrology on Thwaites Glacier	Andrew Hoffman
Offshore Characterization of the Amundsen Sea Embayment Geologic Environment	Caitlin Locke
Ice Fracture, not firn fracture: Quantifying crack propagation through ice at a blue ice zone	Jack Logan
The Polar Rock Repository: furthering knowledge of the Antarctic ice sheet using legacy collections	Erica Maletic
Nonlinear longitudinal stress coupling in glacier and ice sheet flow	Logan Mann
Quantifying Firn Processes in Antarctica Using Radar–Laser Altimetry Bias	Marianna Marquardt
Open Polar Radar Tomographic Swath and Multipass Synthetic Aperture Radar Processing Assessment	John Paden
Past and Future Retreat of Thwaites Glacier: Sensitivity, Calibration, and Sea Level Rise Projections	Mattia Poinelli
Duration versus dates – how can geochronology provide better constraints for ice dynamics models?	Brad Rosenheim
Basal Ice Under Thwaites Glacier: Windows into Subglacial Processes?	Britney Schmidt
Stochastic inversion for subglacial topography: a case study of Pine Island Glacier	Niya Shao
Development of an ICESat-2 land ice mass change product	C. Max Stevens
Glacier-Mélange Feedbacks as a Stabilization Mechanism for Classical Marine Ice Sheet Stability	Paul Summers
Reconstructing Spatial and Temporal Variability in Grounding Zone and Ice Shelf Retreat Around Ross Bank	Magkena Szemak
FAIR enough: Encouraging best practices for data sharing at USAP-DC	Kirsty Tinto
Ice sheet melt suppresses Antarctic snowfall and further accelerates sea-level rise	Olivia Truax
Sediment core curation, sampling, and analytical capabilities at Oregon State University Marine and Geology Repository: opportunities for legacy and novel sediment core studies	Kara Vadman

Title	Presenter
Near-Total Loss of Buttressing Observed on Pine Island Ice Shelf	Sarah Wells-Moran
Accelerations of bedrock motions track changing ice mass balance in West Antarctica	Terry Wilson
Radar Attenuation through the Ross Ice Shelf reveals Melt Shutdown and Accretion of Marine Ice within Basal Channels	Madeleine Yao
The Role of Bedrock Channels in Routing Water Under Thwaites Glacier	Sunme Zhao

Surface Height Increases from Extreme Snowfall Events Obscure Dynamic Thinning Across Antarctica

Susheel Adusumilli[1], Helen Amanda Fricker[2], Michelle Maclennan[3]
[1]University Of Oregon, [2]Scripps Institution of Oceanography, [3]British Antarctic Survey

Anticipated increases in precipitation over the Antarctic Ice Sheet in the 21st century are expected to mitigate its contribution to sea-level change. However, there is limited confidence in model projections of these changes, particularly for extreme events that deposit snow over large areas on timescales of hours to days. Continental-scale observations of snowfall are only available from satellites, but their sampling frequency (typically monthly or longer) prevents the detection of individual events. We use ICESat-2 laser altimetry to estimate ice sheet height changes for the period 2019 to 2024 at weekly to fortnightly time scales. Our data reveal widespread short-term increases in surface height, driven by extreme precipitation events, including the largest Atmospheric River on record ever to make landfall over Antarctica. Overall, our results show that while surface processes dominate height changes across many Antarctic basins on short timescales, dynamic and ocean-driven mass losses still dominate in West Antarctica, and the surrounding ice shelves.

Lessons on model calibration from the Greenland Ice Sheet

Jessica Badgeley[1], Mathieu Morlighem[2], Hélène Seroussi[2]
[1]Applied Physics Lab, University Of Washington, [2]Dartmouth College

State-of-the-art ice sheet model simulations tend to underestimate Greenland mass loss over the past few decades, and they give a large spread around Antarctica mass loss for the same time period. This inability to match historic observations decreases confidence in the projections these models make of ice sheet contribution to sea level. We use the Ice-sheet and Sea-level System Model to investigate how different calibration methods affect a simulation's fidelity to historical observations, and how, in turn, this impacts the projected mass loss. We apply two adjoint-based data assimilation calibration methods to simulate the rapidly changing region of northwestern Greenland: (i) the commonly used snapshot inversion, and (ii) the emerging method of transient calibration. With more observational and physics constraints than the snapshot inversion, transient calibration has been shown to better capture trends in ice dynamics. For simulations calibrated with the snapshot inversion, we find too-slow modeled velocities, leading to an (expected) underestimate of mass loss. With transient calibration, our simulated velocities are less biased, leading to a better fit to observed mass loss. We show that using a calibration method that reproduces historical mass loss leads to greater projected sea level contribution from this region over the coming century. We also show that different calibration methods contribute more to our model spread than different emission scenarios for projections over the next thirty-five years. For Antarctica, these findings imply that improving model fit to the historical period should reduce projection spread, especially in the near term. Questions remain, however, as to how applicable historical calibrations are to simulations spanning decades or centuries into the future, especially for unstable, nonlinear systems such as a marine ice sheet that may yet experience unobserved processes.

Collapse of the Ross Bank Ice Rise

Dr Philip Bart[1], Dr Matthew Danielson
[1]Louisiana State University

Isle-type ice rises are domes on the surface of an ice shelf. The domes correspond to the contact between an ice shelf and an underlying submarine bank. Many tens of ice rises exist at the marine margins of the Antarctic Ice Sheet. These features re-organize and slow the offshore flow of ice and partly maintain the ice sheet in its current configuration. Despite their importance as buttressing sites, little is known about how ice rises change over time. Here, we show that Ross Bank in central Ross Sea was formerly an ice rise. Our reconstruction shows that many tens of small-scale rim moraines record contraction of the ice rise from the flanks and crest of Ross Bank. The close spacing and semi-concentric pattern of ice-rise rim moraines (IRRMs) suggests a progressive loss of buttressing as the ice rise contracted gradually from a large- to a small area prior to an unpinning stage. Following collapse of the Ross Bank Ice Rise (RBIR), the central part of the Ross Ice Shelf (RIS) contracted partly back to the WAIS grounding line before re-establishing in its current configuration. It is not known what caused the RIS to thin and unpin or why the central part of the RIS collapsed and then reformed. Our study validates concern that ice shelf thinning could trigger significant and unexpected changes in the extent and volume of grounded and floating ice. The paleo-perspective demonstrates that more than 80% of the extant isle-type ice rises – with their small areas – are approaching a collapse stage. At current local rates of ice shelf thinning, three isle type ice rises will collapse before the end of the 21st century.

NSF Center for Oldest Ice Exploration: Recent results, future plans and thoughts for the broader community

Ed Brook[1], COLDEX Community
[1]Oregon State University

The NSF Center for Oldest Exploration (NSF COLDEX) is a Science and Technology Center supported by the NSF Office of Integrative Activities and Office of Polar Programs, which began operations in late 2021 and is funded through 2026. COLDEX is headquartered at Oregon State University but involves a total of 15 different institutions. A renewal proposal (2026-2031) is in review. COLDEX is exploring the Antarctic ice margin and interior for the Earth's oldest ice and developing ice core records that extend through the Pliocene and into the Miocene, with the oldest ice so far discovered between 6 and 7 Ma. COLDEX also uses the integrative nature of the Science and Technology Center program in efforts to broaden participation in polar science, provide educational programs and knowledge transfer within and outside of the scientific community.
This presentation will review COLDEX activities and recent results, discuss the proposed phase 2 programs, and offer thoughts about intersections with other polar communities and projects.

West Antarctic Ice Sheet Instability during Pleistocene Interglacials: Insight from foraminifera and paleotemperature reconstructions

Imogen Browne[1,2], Samantha Bombard[3], R. Mark Leckie[3], Molly Patterson[1], Melissa Berke[2], Abby Hartzer[2], Juliane Müller[4], Sunghan Kim[5], Jim Marschalek[6], Tina van de Flierdt[6], Georgia Grant[7], Ruthie Halberstadt[8], Laura De Santis[9], Rob McKay[10], Denise Kulhanek[1,11], The Expedition 374 Scientists[12]
[1]Binghamton University, [2]University of Notre Dame, [3]University of Massachusetts, [4]Alfred-Wegner Institute, [5]Korea Polar Research Institute, [6]Imperial College, [7]Earth Sciences New Zealand, [8]University of Texas at Austin, [9]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, [10]Victoria University of Wellington, [11]Christian-Albrechts-University of Kiel, [12]International Ocean Discovery Program

Although the West Antarctic Ice Sheet (WAIS) is not currently undergoing ice mass loss in the Ross Sea sector, geologic data and models indicate that this region may have experienced retreat during warmer-than-present intervals of the mid- to Late Pleistocene. Understanding the magnitude of ocean warming and cryosphere response during past interglacials is important for predicting future ice mass loss, sea level rise, and changes to deep ocean circulation expected with ongoing warming. To provide insight into WAIS dynamics over the past ~500,000 years, we reconstruct depositional environments and oceanography at International Ocean Discovery Program Site U1524, drilled into a channel levee deposit on the continental slope of the Ross Sea. Sediment deposition at Site U1524 is influenced by outflow of cold, corrosive Antarctic Bottom Water (AABW) from the Ross Sea shelf and by the westward-flowing Antarctic Slope Current which entrains fresh surface water from the Amundsen Sea and relatively warm Circumpolar Deep Water (CDW) which is transported at depth in the lower limb of the Ross Sea Gyre.

Using sedimentologic data, sedimentary X-ray fluorescence (XRF) data, assemblage and stable isotope data from calcareous foraminifera, and biomarker proxies for surface ocean temperature, our results demonstrate that glacial-to-interglacial transitions are associated with sediment reworking from the shelf and deposition from icebergs, followed by an increase in foraminifer abundance during Marine Isotope Stages (MIS) 11 and 9. Increased foraminifer abundance and presence of the subpolar species Neogloboquadrina incompta and Epistominella exigua, associated with high export production, indicates the onset of warm, highly productive open-marine conditions during MIS 11 and 9, perhaps associated with decreased formation of AABW, which created oceanographic conditions conducive to carbonate preservation. A lack of foraminifer preservation in interglacial intervals after MIS 9 is associated with surface ocean warming, change in sediment provenance, and decreased sedimentation rate, which may have resulted in poor carbonate preservation. Finally, we integrate this multi-proxy reconstruction of Ross Sea glacial-interglacial cycles with numerical ice-sheet model simulations of transient ice sheet evolution through the Pleistocene, leveraging our data to contextualize regional ice sheet behavior.

Debris-rich basal ice layers from Mercer Ice Stream, West Antarctica: Implications for ice stream basal dynamics

Dr Tim Campbell[1], Dr Mark Skidmore[2], Robert Zook, John Winans, Dr John Priscu[3]
[1]Montana State University, [2]Stockholm University, [3]Desert Research Institute

Constraining the basal dynamics beneath West Antarctic ice streams is important for predicting ice flow to the sea and associated sea level rise. The properties of the underlying bed and basal thermal state determine the amount of basal sliding, frictional resistance, and overall ice flow. However, the spatial and temporal variability of these basal properties remains poorly constrained due to the limited number of direct observations and measurements. Here, we identify a ~5 m thick sequence of basal ice layers entrained onto the sole of the Mercer Ice Stream (West Antarctica). Analysis of borehole wall imagery revealed that the sequence consisted of two distinct basal ice facies differentiated by sediment content. The lowest basal ice layer consisted of solid facies and contained 25x more sediment by volume than the overlying sequence of dispersed facies. We describe potential basal ice formation processes using recent models developed for frozen fringes and regelation and discuss the implications for upstream basal conditions and meltwater activity beneath the Mercer Ice Stream. The entrainment of sediment requires high effective pressures for ice to infiltrate the underlying sediment, forming a frozen fringe, which is indicative of a period with low meltwater availability and slow ice flow. We will discuss potential mechanisms for the formation of the dispersed facies, relating to meltwater availability, basal thermal regime and effective pressure. Collectively, our results provide constraints on subglacial conditions and processes beneath a West Antarctic ice stream.

Model experiments coupling grounding-zone sedimentation and ice dynamics: grounding zone wedges, retreat, and stability

John Erich Christian[1], Alexander Robel[2], Ginny Catania[3], Leigh Stearns[4], Lauren Miller[5], Santiago Munevar Garcia[5]
[1]University of Oregon, [2]Georgia Institute of Technology, [3]University of Texas at Austin, [4]University of Pennsylvania, [5]University of Virginia

Ice streams deposit sediment at their grounding lines, where ice reaches flotation. Grounding Zone Wedge (GZW) deposits indicate standstills in past grounding-line retreat, and are thought to stabilize grounding lines by reducing local water depth. However, the mechanisms of GZW growth are uncertain, as are the effects of sedimentation on a retreating grounding line prior to GZW formation.

We present simulations with a 1-D model coupling ice flow and sediment transport. The model considers both the convergence of deforming sediments and melt-out of sediment entrained in basal ice, which are assumed to correspond to subglacial vs. proglacial deposition patterns. The model grid is refined near the grounding line to resolve small depositional features and their effect on ice dynamics.

The model simulates the growth of low-profile, prograding, asymmetric features consistent with observed GZWs. We find that the characteristic shape of GZWs arises from the coupling of sedimentation and ice dynamics. This mechanism is consistent with either deforming or entrained sediments, but depends on localized deposition in the grounding zone. The model also allows us to explore previously hypothesized sedimentation feedbacks during grounding-line retreat. We find that when external factors initially slow retreat, localized sedimentation may turn a transient slowdown in retreat into a long standstill, even when the large-scale ice fluxes are far out of equilibrium.

While our model necessarily simplifies a complex boundary between ice, ocean, and bed, sensitivity analyses illustrate some key controls on GZW formation and grounding-line stability. In particular, we find that the spatial pattern of sedimentation affects the potential for stabilizing feedbacks during retreat, as well as the aspect ratios of GZWs that do form. We explore this in our model via the relative amounts of subglacial vs. proglacial deposition. However, we expect that additional subglacial processes should also modify the pattern of sedimentation. We close by discussing several such areas where insights from observations, lab experiments, and process-specific models may help improve coupled ice-flow and sediment models.

Radar swath imaging: a panacea for mapping the ice-sheet bed?

Dr. Knut Christianson[1], Dr. Andrew Hoffman[2], Dr. Nick Holschuh[3], Dr. John Paden[4]
[1]University of Washington, [2]Rice University, [3]Amherst College, [4]University of Kansas

Radar swath imaging is a substantial advance in mapping ice-sheet beds. Instead of conventional one-dimensional profiles of ice thickness, radar swath technology produces two-dimensional digital elevation models (DEMs) from data alone, without interpolation or statistical assumptions. The result is kilometer-scale cross-track swaths of ice-sheet beds at unprecedented spatial resolution (~20 m horizontal posting and ~10 m vertical resolution). However, radar swath imaging still has technical and interpretative limitations. Technically, radar swath imaging requires basal roughness to generate measurable off-nadir backscatter, and the magnitude and orientation of roughness may be unknown when the radar survey is designed. Interpretatively, skin drag and form drag remain convolved in ice-flow simulations using swath topographies due to still sub-resolvable basal roughness. Radar swath imaging has applications beyond topography. For example, recent modeling also suggests that long-wavelength subglacial roughness can induce shear bands of concentrated ice deformation originating from topographic highs, which may lead to englacial reflections due to a contrast in crystal-orientation fabric. Radar swath imaging can evaluate this hypothesis by imaging englacial along- and across-track specularity.

Here, we present and discuss advantages and limitations of swath radar surveys in four diverse glaciological settings: an active ice stream (Thwaites Glacier), the onset of fast flow in interior Greenland, the bottleneck between the East and West Antarctic ice sheets, and the flank of the East Antarctic plateau. Our results reveal that swath radar is a powerful tool for subglacial geomorphology. We find that interpretations of swath topographies can elucidate past ice-flow conditions and that assumptions relating basal ice velocity and subglacial landform morphometrics may require revision. We also present examples of radar swath imaging of cross-track reflector slopes, which has applications for radar repeat-pass interferometry. We close by presenting recommendations for radar survey coverage and orientation to maximize scientific yield from radar swath imaging.

The West Antarctic Ice Sheet in Undergraduate Curriculum

Dr. Knut Christianson[1]
[1]University of Washington

The West Antarctic Ice Sheet is distant and remote, both physically and conceptually. As with most other subjects that also do not have immediately tangible impacts, lessons that focus on West Antarctica can be difficult to relate to students' lived experiences, and thus are less approachable and often have less impact than more familiar topics. Here, I discuss and solicit feedback regarding strategies I have implemented in undergraduate courses in an attempt to make important concepts in Antarctic glaciology more accessible to undergraduate students. Conceptually, I have constructed lessons on glacier mass balance (mass continuity), ice flow (stress, strain, and material rheology), glacier geomorphology (landscape evolution), and glacier equilibrium sensitivity, equilibrium response, and transient response (glaciers as dynamic systems). I take two approaches to make these concepts more generally applicable to both glaciological but also other Earth sciences questions in multiple career paths, from academia to geotechnical and environmental engineering and even medical imaging. First, I relate these concepts to more general topics in Earth sciences, including: heat and mass flow, landscape evolution, and dynamic system response (reservoirs and response times in other Earth systems), and to topics with societal implications, such as: hydropower generation, water resources management, ecosystem/glacier co-evolution, and understanding of local landscapes. Second, I present applications of common geophysical instrumentation (ground-penetrating radar, terrestrial radar interferometry, terrestrial laser scanning, Structure-from-Motion photogrammetry, and GNSS) in both glaciological and other settings, including other geological applications but also applications to our built environment. When opportunity allows, we also use the geophysical instrumentation in coursework in the multiple settings mentioned above. Finally, I will share common frameworks for lessons that I have applied in three different courses: “Field Methods in Remote Sensing”, “Principles of Glaciology”, and “Field Methods with GIS”. Hopefully, this presentation can serve as a discussion prompt for effective glaciology curriculum in Earth sciences.

Rapid small-scale fracturing at pinning points prime ice shelves for tabular calving events

Dr Fiona Clerc[1], Prof Ching-Yao Lai[1], Dr Ellianna Abrahams[1]
[1]Stanford University

The calving of tabular icebergs is an important mechanism by which ice shelves lose mass. Yet, the processes which drive calving are poorly understood. Often, calving events can be attributed to rifts initiating at pinning points (locations where the ice shelf is grounded at a submarine high), but it is unclear whether these pinning points conversely exert a stabilizing influence by imparting large compressive stresses, inhibiting tensile fracturing. Here, we compile time series of Sentinel-1 and Worldview satellite imagery for three pinning points: the McDonald Ice Rumples (MIR) on Brunt Ice Shelf, Gipps Ice Rise (GIR) on Larsen C, and Ice Rise C (IRC) in Pine Island Bay. At all settings, we observe rapidly evolving small-scale fractures (SSFs) which emanate radially from the pinning point. These SSFs are typically <50 m wide, up to several kilometers long, tightly spaced (50-100 m apart), and evolve on timescales of weeks-years. However, despite the similarities of these SSFs across various settings, the underlying ice shelf geometry and rheology lead to different outcomes. At IRC, glaciological stresses are low and mostly compressional, and the SSFs remain stable. At the GIR, the SSFs are advected into an extensional regime downstream of the pinning point, until they seemingly coalesce into large rifts. At the MIR, heterogeneities in ice viscosity and strength control SSF evolution. We leverage spatiotemporal filters to isolate the SSF signal and find that SSFs form in weak but stiff meteoric ice and are arrested in strong but soft sea ice cement. These SSFs ultimately coalesce into the North Rift, playing a key role in initiating a sequence of large calving events which altered the geometry of Brunt Ice Shelf. We suggest monitoring of SSFs, coupled with knowledge of ice shelf stress and structure, can provide insight into the future vulnerability of ice shelves to calving.

Probabilistic Inversion of Sub-ice-shelf Bathymetry around Antarctica

Michael Field[1], Emma MacKie[1]
[1]University Of Florida

Sub-ice-shelf bathymetry controls how circumpolar deepwater moves up the continental shelf and circulates below ice shelves, thus influencing the rate of basal melting and the destabilization of ice shelves around Antarctica. Sub-ice-shelf bathymetry is best inferred using airborne gravity, which is sensitive to the large density contrast between water and rock. However, gravity inversions are poorly constrained and require the interpolation of the Bouguer disturbance, which represents crustal density anomalies and crustal thickness. Previous inversions have typically interpolated the Bouguer field deterministically, producing a single inversion result and failing to robustly capture the spatial uncertainty of the problem. Our approach uses geostatistical interpolation to create realizations of the gravity field that represent different scenarios of subglacial geology. We solve each inversion in the ensemble using a Markov Chain Monte Carlo approach that stochastically perturbs the bathymetric surface until there is a close fit between the observed and forward modeled data. We present ensembles of sub-ice-shelf bathymetry around Antarctica inverted using a continent-wide gravity compilation. Our ensemble members differ from previous estimates by hundreds of meters with important implications for sub-ice-shelf circulation. Our ensembles can be used to assess how the uncertainty in bathymetry translates to uncertainty in ice shelf basal melting and ice mass loss.

Gleaning additional insight from the satellite record with observations of waves on glaciers

Max Filter[1], Dr. Erik Tamre[1], Dr. Bryan Riel[2], Dr. Brent Minchew[1,3]
[1]Massachusetts Institute Of Technology, [2]Zhejiang University, [3]California Institute of Technology

Glacier flow velocities vary over timescales ranging from hours to millennia, often in response to nonlocal forcings driven by tides, hydrology, and calving. Flow velocity time series are derived from remote sensing observations, all collected within the past few decades. These time series allow for constraints on flow velocity variations in response to forcings at higher temporal frequencies, but due to the nonlinear nature of glacier flow, the constraints cannot be directly extrapolated to timescales longer than the available satellite record. As a result, the mechanics of glacier flow at decadal and longer timescales are not well understood. Here, we develop a physical model of the response of fast-sliding, laterally confined glaciers to periodic forcing. We find that observations of wave propagation at Pine Island Glacier, West Antarctica, are consistent with a plastic bed and a viscosity corresponding to temperate ice, in agreement with previous studies. From this model, we derive an analytical expression for the dispersion relation, which describes the dependence of stress transmission within the glacier on forcing frequency. We expect this to provide testable predictions for future ice flow at decadal and longer timescales, which may in turn decrease uncertainty in sea-level rise projections for the next century.

Constraining ice thickness and basal conditions in Antarctic grounding zones using satellite observations and viscous beam modelling

Dr Bryony Freer[1,2], Dr Oliver J. Marsh[2], Dr Alex T. Bradley[3], Prof. Helen Amanda Fricker[1]
[1]Scripps Institution Of Oceanography, [2]British Antarctic Survey , [3]King's College London

The dynamics of the Antarctic Ice Sheet and its future contribution to sea-level rise are highly dependent on the behaviour of the surrounding ice shelves. A particularly critical region is the grounding zone (GZ), where ice transitions from grounded to floating and basal properties, ocean forcing, and ice dynamics interact. Distinctive surface undulations – which we term “grounding zone viscous bumps (GZBs)” – can form as ice responds viscously to ungrounding across this sharp change in basal stress. We propose that GZBs can serve as an independent proxy for grounding line (GL) location and reveal information about basal conditions. We map GZBs around the Ross Ice Shelf using high-resolution digital elevation models and ICESat-2 laser altimetry, assessing how their dimensions vary between the major Trans-Antarctic outlet glaciers and Siple Coast Ice Streams. Integrating these observations with a viscous beam model, we can locate the GL, infer the relative strength of basal drag and ice viscosity, and improve critical estimates of ice thickness and basal slope across the GZ. ICESat-2 observations showing the temporal evolution of a GZB at a retreating GL provide further insight into tidal processes and long-term retreat, and could help identify regions susceptible to future instabilities. This study demonstrates the value of integrating satellite observations with process models to constrain poorly known glaciological parameters around Antarctica.

The Earth Dynamics Geodetic Explorer (EDGE) mission: A swath-imaging multifunction lidar for tracking the 3D structure of terrestrial ecosystems and surface topography of ice

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The Earth Dynamics Geodetic Explorer (EDGE) mission is a swath-imaging satellite laser altimeter designed to measure geodetic surface height and 3D vegetation structure with unprecedented spatial coverage and accuracy across Earth's land and ice regions. EDGE was selected for Phase A funding under NASA’s Earth System Explorer program and if successful, will launch in 2030 for a 2+ year mission. EDGE’s measurement approach, design, and implementation builds on the success of NASA's Global Ecosystem Dynamics Investigation (GEDI), Ice, Cloud, and land Elevation Satellite (ICESat) & ICESat-2 and Land, Vegetation, and Ice Sensor (LVIS) laser altimeters. EDGE’s key innovation is five 120-m wide “mini-swaths” that observe Earth’s ice, vegetation, and coastal corridors in 3D with 10× better spatial coverage than previous missions, bringing into focus previously unmapped features. Combined with increased accuracy (<3 m horizontal and <8 cm vertical on low slopes), this enables direct measurement of change at the fine spatial scales of driving processes; a capability previously only possible with airborne systems. EDGE flies on a WorldView Legion Maxar 500 spacecraft, providing the agility needed for rapid and precise targeting of high-priority regions that are of critical national importance. EDGE’s flight-experienced, interdisciplinary Science Team supports the needs of an extensive user community, and the mission has attracted 75+ letters of support. EDGE marks a new era in satellite laser altimetry, and by serving as the DS-recommended Explorer component of STV and addressing many Surface Topography and Vegetation (STV) objectives, it provides a stepping stone to the anticipated 2027 DS STV mission, while also establishing a clear path toward a future global lidar constellation.

The Sacred of the South: Public Engagement with West Antarctic Ice Sheet Science through Art

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Diatoms are both life-sustaining organisms and key proxies in Antarctic and ocean sciences. They generate up to half of Earth's oxygen, draw down significant carbon dioxide, and underpin the ocean food web. In the Southern Ocean, their abundance is driven by cold, nutrient-rich waters, extended daylight, and dynamic circulation. When diatoms die, many sink to the seafloor, where their microfossils record past oceanographic and climatic conditions, providing essential insights into the history of the WAIS and its responses to climatic change.

Despite their global and scientific importance, diatoms remain virtually unknown to the public. My work bridges this gap by integrating scientific accuracy with artistic interpretation to foster awareness and emotional engagement. This series presents several Southern Ocean diatom species as "icons," using watercolor, mixed media, and digital painting. Drawing on religious iconography and the atmospheric traditions of artists such as Frederic Edwin Church, each work situates diatoms in Antarctic landscapes that follow a visual journey from the open ocean to the continent's icy margins.

The palette shifts from cool to warm tones, eliciting the progression of a warming climate and melting ice shelves—a symbolic reminder of WAIS vulnerability. Through this framing, diatoms are presented as both agents of global life and indicators of change. Viewers are invited to engage first with beauty, and then with inquiry: What am I seeing? Why does it matter?

By incorporating humor—such as the "tiny pants diatom" nickname for Eucampia antarctica—I lower barriers to engagement while maintaining the urgency of the climate message. Combined with explanatory text, this approach can reach audiences ranging from schoolchildren to policymakers, showing that narrative and visual storytelling can help translate a technical concept like "proxy records" into an accessible, emotive, and memorable experience.

In the context of rapid WAIS change, public engagement is critical. By elevating diatoms as symbolic and scientific touchstones, this work invites audiences to see them as integral to planetary health and to recognize that their fate—and the fate of Antarctica—is inextricably linked to our own. I explore additional art + science pairings I have worked on to further explore how powerful this combination can be for public engagement and awareness.

From Drill Site to Insight: Engaging Students and the Public with West Antarctic Ice Sheet Science through SWAIS2C Education and Outreach

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Capturing, engaging, and motivating a broad and diverse audience with clear, scientifically accurate, and compelling information about Antarctic ice-sheet change is an enormous challenge. The Sensitivity of the West Antarctic Ice Sheet to 2°C (SWAIS2C) Project is an international scientific drilling program operating ~1,000 km from Scott Base and McMurdo Station, tasked not only with conducting groundbreaking science, but also with sharing that science widely and creatively.

Our approach begins with identifying what people need to know—and, just as importantly, what they don't yet know—then building knowledge in a logical, accessible, and engaging progression. We develop materials that explain the science, enhance understanding, and inspire action—while offering something for audiences of all ages. These include fully illustrated educational units, teacher guides, and STEAM activities; profiles of team members from diverse research backgrounds; and an empowering action plan for anyone who wants to make a difference. Our resources are scientifically robust, adaptable to a range of educational settings, equally useful for adults, and visually rich.

Today's audiences—especially younger audiences—are highly visual and accustomed to receiving information in short, media-rich bursts. Many are also drawn to the graphic novel format. To meet them where they are, we incorporate graphic formats and an interactive, gamified learning experience. Drawing on the complementary expertise of the three authors—spanning Antarctic science, formal and informal science education, publishing, textual and visual storytelling, and digital media—we create resources that are scientifically rigorous, pedagogically effective, and visually engaging.

At WAIS Workshop 2024, we previewed a new resource: an interactive animation that allows users to raise and lower ocean temperatures to grow or melt an ice shelf, observe the deposition of clasts, sediment, and microfossils, and explore how sediment cores reveal the effects of past climate change on ice shelves. Now ready* for use, this tool—together with other SWAIS2C outreach products—supports hands-on exploration and deepens understanding of proxy data, ice-shelf dynamics, and the broader implications for global sea-level rise in a warming world.
* Fingers crossed.

The program also helps scientists strengthen their communication skills by providing ready-to-use outreach tools and showcasing the strengths of individual researchers. This reduces the time required for engagement while expanding the reach and impact of the science.

In an era of constant media competition, science communication must be memorable, shareable, and adaptable. The SWAIS2C E&O program demonstrates how a creative, multimedia-rich approach—rooted in accurate science and framed through compelling narratives and accessible visuals—can spark curiosity, build understanding, and inspire action to protect our polar regions and the climate, ocean, and life-support systems they sustain.

The impact of grounded icebergs on Prydz Bay, Antarctica

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The exchange of dense water and heat between Antarctic ice shelf margins and offshore waters is sensitive to the regional distribution of icebergs and sea ice. This study numerically models the impact of the Cape Darnley Ice Barrier (CDIB) and Iceberg D-15 on regional cross-shelf exchange and ice shelf basal melt in Prydz Bay. Removing the CDIB is found to enhance wind-driven circulation, onshore intrusions of warm Circumpolar Deep Water (CDW), and basal melt at the Amery Ice Shelf while also decreasing dense water formation. Removing Iceberg D-15 also increases CDW intrusions and decreases dense water formation, but to a lesser extent. These simulations indicate that the impact of icebergs on poleward heat flux depends on their location relative to local ice shelves and bathymetry.

Early Pliocene Current Strength Variability off West Antarctica Based on a Particle Size Record from the Resolution Drift, Amundsen Sea.

Ms Monika Ghimire[1], Dr Sandra Passchier[1]
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Loss of ice sheet in West Antarctica is a major contributor to global sea level rise. The stability of the West Antarctic Ice Sheet under warmer than present conditions, likely the Early Pliocene is a critical uncertainty in projecting future sea-level rise. To address this, we investigate bottom current variability during the Early Pliocene using particle size analysis of sediment cores (U1532C and U1532G) recovered from Resolution Drift in the Amundsen Sea. Grain size measurements were conducted using a Malvern Mastersizer 3000 laser diffraction analyzer, which enabled high-resolution quantification of the sortable silt fraction (10–63 μm) and calculation of mean sortable silt size (Mean SS), both of which serve as proxies for bottom current strength. Our grain size result shows fine grained silts and clays with minor sand content, indicating deposition under generally low energy conditions interspersed with episodic high energy events. Our result shows an interval spanning ~4.3 to 4.6 Ma with increased Mean SS values, suggesting intensified bottom current activity during this period. Two distinct current regimes appear to have influenced sedimentation at this site: (1) the offshore Antarctic slope current which maintained persistent background current activity, and (2) a variable coastal current system possibly hyperpycnal flows, sensitive to ice sheet dynamics and meltwater release. Our findings suggest that ocean circulation along the West Antarctic margin was dynamic during the Early Pliocene, with significant variability in bottom current strength due to icesheet-ocean interaction.

xOPR -- Reproducible access to over 20 years and 2 petabytes of airborne measurements in Antarctica

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The Open Polar Radar (OPR) project provides a unified data processing pipeline for over 3.5 million line-km of airborne radar sounder measurements collected across campaigns from multiple institutions and multiple instruments. We showcase work from the new xOPR python library, which is an open source library for searching, accessing, and loading this important data in a modern and cloud compatible way. By leveraging open science geospatial technologies, we have developed simple reproducible workflows to harmonize these observations with ice sheet models.

In addition to highlighting capabilities and new access to OPR data, we share lessons learned from developing software infrastructure to support access to roughly 2 petabytes of polar radar sounder data stored in a mix of legacy formats, including HDF5, older Matlab formats, and a range of custom binary formats. Our SpatioTemporal Asset Catalog (STAC) was built and hosted to facilitate geospatial search with standard tools, and continues to grow as we add more data. The xOPR library abstracts away as many of the format differences as possible to simplify uniform community access to the data, converting to cloud optimized formats when feasible and using virtual Zarr files as intermediate representations where needed.

Uncovering Seasonal Subglacial Groundwater Dynamics in Antarctica using Geologically Constrained Modeling and Satellite Altimetry

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The influence of subglacial hydrology on ice flow is key to modeling the future potential evolution of the Antarctic ice sheet, but many characteristics of the system are poorly constrained. Water can permeate into sedimentary basins underlying these ice-base hydrologic systems and form a deeper (> ~10 m below the ice base) subglacial hydrologic system referred to as groundwater. Magnetotelluric and seismic observations have inferred the presence of groundwater systems beneath a fast-flowing portion of the West Antarctic Ice Sheet, suggesting there may be exchange between groundwater reservoirs and water systems at the ice-sheet base. However, existing subglacial hydrology models do not consider groundwater systems and their potential interactions with conventional hydrology systems. Seasonal variations in Antarctic snowfall influence subannual ice sheet mass changes, which may in turn modulate groundwater exfiltration – potentially introducing a previously uncharacterized seasonal variability to the subglacial water budget. Such seasonal variability in a groundwater system has been observed in Greenland, motivating an investigation into Antarctic subglacial groundwater processes and their potential impact on ice-sheet dynamics.

Here, we examine the potential for seasonal variability of groundwater exfiltration in Antarctica using a one-dimensional Darcy flow model for porous sediments overlain by glacier ice. This model uses rates of ice-surface elevation change derived from Ice, Cloud, and land Elevation Satellite 2 (ICESat-2) laser altimetry and incorporates geological constraints such as sedimentary basin distributions and sediment permeability. We find that groundwater exfiltration flux varies over short timescales and across regions. We also compare our results with ice-sheet basal melt flux estimates from the Ice-Sheet Model Intercomparison Project for CMIP6 (ISMIP6) ensemble to contextualize our groundwater exfiltration results and assess the potential for seasonal groundwater processes to impact Antarctic ice flow. Our work constrains the seasonal contribution of groundwater exfiltration to the subglacial water budget and shows how continued ice-sheet thinning may amplify this previously uncharacterized component.

The Influence of Bed Topography on Water Column Mixing and Ice-Ocean Interactions at Erebus Glacier Tongue, Antarctica

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Marine-terminating glaciers connect grounded ice sheets to the ocean, where interactions with water of varying hydrographic properties occur over a range of spatial and temporal scales. Here, we discuss data gathered with the remotely operated vehicle Icefin from beneath Erebus Glacier Tongue (EGT) in McMurdo Sound, Antarctica, that show how regional ocean circulation interacts with local seafloor topography to drive spatially variable melting along the glacier underside. Our measurements reveal that a subglacial ridge ∼30-50 m tall and ∼300 m wide runs nearly flow-parallel down the central axis of the tongue and inhibits under-ice circulation to create two distinct water masses on either side. This ridge appears to carve a channel into the overlying ice that is maintained from the grounding zone to the calving front, suggesting the ridge is forcing glacial-scale topography into the ice. We find that the ocean on the northern side of the glacier is colder, more saline, and less oxygen rich than the southern side, forced by the isolation of this water mass due to the subglacial seafloor topography and the geometry of Ross Island and the Dellbridge Islands to the north of EGT. A channel within the seafloor along the southern edge of the glacier allows for the delivery of more recently-ventilated water towards the southern side of the central ridge and the grounding zone. Melt rates throughout the cavity are moderate, between 1.3-3.0 m yr-1, and the maximum observed concentration of glacial meltwater (GMW) is 0.25 mL L−1. Near the grounding zone, topography on the seafloor initiates roughness on the recently grounded ice, creating a basal morphology distinct from other areas beneath the glacier. These observations are relevant for understanding grounding zone processes and are broadly applicable to ice shelves around Antarctica.

Random Forest Parameterization of Antarctic Subglacial Hydrology

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Rapid ice flow of major Antarctic ice streams is accommodated through fast basal slip and controlled in part by basal effective pressure. Projected ice sheet thinning and grounding line retreat implies changes in the basal effective pressure distribution and therefore in basal friction. Yet, it remains challenging to model effective pressure changes across sufficiently large portions of the ice sheet and on centennial timescales given the computational intensity of subglacial drainage models relative to ice sheet models and that calibration often requires a large number of model evaluations. To overcome this computational burden, we train a Random Forest parameterization of basal effective pressure that closely approximates the popular Glacier Drainage System (GlaDS) subglacial drainage model. Effective pressure is modelled with random forest regression based on ice-sheet geometric characteristics. The random forest model is trained using ensembles of GlaDS simulations on 5 basins: the Amundsen Sea Embayment, Aurora Subglacial Basin, Amery Ice Shelf Catchment, Denman Glacier and Recovery Ice Stream. We assess the model’s performance using leave-one-out cross validation, retraining the model while holding out GlaDS simulations on each basin individually. We are using the trained random forest model to predict a seamless continent-wide effective pressure field for the present-day ice sheet configuration. The model can be used for different ice-sheet configurations without retraining, enabling projection of basal effective pressure changes in response to future thinning and grounding line retreat.

Geophysical Observations of Subglacial Hydrology on Thwaites Glacier.

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A system of subglacial lakes drained on Thwaites Glacier in 2012–2014, and 2017-2018. To continue monitoring efforts and understand the impact of subglacial hydrology on erosion and ice mechanics, we extend the elevation and ice-velocity time series on Thwaites Glacier through austral winter, 2025. We also collected new GNSS, phase-sensitive radar, and active-source seismic data over these lakes during the 2022-2023 and 2024 austral summers. These new observations document a second lake drainage cycle in 2022-2023. In situ GNSS and satellite velocity observations show temporary < 3 % speed fluctuations associated with lake drainages. In agreement with previous studies, these observations suggest that active subglacial hydrology has little influence on thinning and retreat of Thwaites Glacier on decadal to centennial timescales. The new geophysical data, however, reveal other impacts on the Thwaites Glacier system. Phase-sensitive radar data reveal non-linear englacial vertical strain in the vicinity of ridges in topography and basal shear stress that control the position of the subglacial lakes. Swath radar and active-source seismic imaging indicate enigmatic large-scale water-saturated sediment structures that coincide with active subglacial lake locations. The mechanisms of water and sediment movement through these lakes remains unclear, but these data present a new richer view of a subglacial lake system under an ice stream.

Stabilizing factors of Cook Ice Shelf and Cook West Glacier, East Antarctica

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The loss of mass from the Antarctic Ice Sheet has the potential to be the largest contributor to global sea level rise by 2100. Although much of the focus is on losses from the West Antarctic Ice Sheet (WAIS), recent satellite records show that marine-based basins of the East Antarctic Ice Sheet (EAIS) are also starting to lose mass. One of these, the Wilkes Subglacial Basin (WSB), is drained by the approximately 100 km wide Cook Glacier. We focus on the “Cook West” region that encompasses a narrow, thick and rapidly flowing tidewater glacier whose calving front is close to the classical maximum thickness for “Marine Ice Cliff Instability” (MICI). The glacier terminates in an embayment that is frequently filled with landfast sea ice. The eastern side of the embayment consists of a highly fractured region reminiscent of Thwaites Glacier Tongue before its retreat. The Cook West region experiences a complex interplay between the calving glacier, landfast ice, grounded icebergs, and the ocean. The landfast ice, whose presence depends on both the coastal topography and grounded icebergs, appears to influence timing of glacier calving events through buttressing. We expect that it will also modify air-sea exchanges of heat, salt and momentum, thus changing the ocean heat content and circulation patterns and thereby altering ocean impacts on the calving front and the rough eastern ice shelf margin of the embayment. Better understanding of this complexity is needed to determine the controls of ocean-ice feedbacks on current and future ice loss. We use a combination of remotely sensed parameters – surface heights from ICESat-2, SWOT, and Maxar WorldView stereo photogrammetry; and velocities from Sentinel-1 synthetic aperture radar – to examine this system, focusing on the various processes and feedbacks contributing to the processes that currently stabilize Cook West Glacier. We also review our new understanding of pathways of warm water into Cook West based on updated bathymetry estimates determined from grounded icebergs.

Investigating Seasonal Glacier Fluctuations in Northeast Greenland Using Physics-Informed Machine Learning

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The Greenland Ice Sheet is losing mass due, in part, to the recent speedup of many of its outlet glaciers, including Zachariæ Isstrøm (ZI), a large outlet glacier in the northeast region of the ice sheet. Not only does ZI play an important role in the ice sheet's surface mass balance, but it also exhibits marked seasonal variability, observed in both glacier flow speeds and the terminus position. Compared to its neighbor Nioghalvfjerdsfjorden (79N), ZI does not have a floating ice tongue and is predicted to retreat much faster despite being subject to similar environmental forcings. Recently, studies examining a small number of large outlet glaciers have also linked the formation, build-up, and subsequent break-up of proglacial mélange to seasonal variability through its impact on the timing of glacier advance and retreat. Still, the relative impact of mélange and other variables, such as terminus position and meltwater runoff, on glacier flow and the extent to which they propagate further upstream remains unclear. Here, I propose to characterize seasonal patterns of glacier flow and retreat at ZI and 79N to determine how meltwater, mélange, and terminus position drive changes in ice velocity and gain insight into the glaciers' potential future changes. Together, these results will provide a deeper understanding of how glacier sensitivity (and thus, ice mass loss) to environmental conditions evolves over time, particularly in the event of ice tongue collapse as observed at ZI, and expand our knowledge of two of the largest and most significant Greenland outlet glaciers.

The control of glacial isostatic adjustment and grounding-zone-wedge sedimentation on the evolution of ice stream stability in the Ross Sea (West Antarctica) over the last deglaciation

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Since the Last Glacial Maximum (LGM), ice streams in the Ross Sea (West Antarctica) retreated hundreds of kilometers to their present-day grounding zone positions. Over this time, the bathymetry of the Ross Sea transformed, as glacial isostatic adjustment caused crustal deformation. This change in bathymetry affected relative sea level (RSL), which strongly modulates the stability of marine-terminating ice sheets. We explore how glacial isostatic adjustment influenced RSL and grounding-zone evolution across the Ross Sea Embayment since the LGM by performing a suite of grounding line stability simulations (n>106) sampling a range of glaciological conditions. Our simulations predict potential stable grounding line positions in the Ross Sea on LGM bathymetry corrected for glacial isostatic adjustment as well as present-day bathymetry. We find that glacial isostatic adjustment migrates stable grounding zone positions from near the continental shelf edge at 20 ka to near the modern grounding zone at present day. This shift is driven by RSL rise towards the shelf break caused by far-field ice-sheet melt, in combination with uplift upstream, which migrates stable grounding zones towards the present-day coastline. Stable grounding zone positions are not prominent near the present-day grounding zone until sufficient uplift occurs within the interior of the Ross Sea Embayment (~6 ka). Our results bolster the claim that glacial isostatic adjustment has acted as a stabilizing feedback mechanism for marine terminating ice streams, whether the grounding zone is at the maximum position near the continental shelf edge or at the present-day minimum.

Effect of the flow-law exponent on ice-stream sensitivity to melt

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The flow-law exponent, n, defines the relationship between stress and strain rate in ice. Growing evidence suggests that n ranges from 1 to 4 in the ice sheets rather than taking the single, commonly used value of 3. A larger exponent implies that ice-flow speeds are more sensitive to changes in stress and therefore melt. However, volume change is not necessarily proportional to ice-flow speed, so the sensitivity of ice loss to n may vary. Flow laws also include a prefactor calibrated for each n, further complicating how n affects glacier behavior. We use a suite of idealized experiments to show how model response to an increase in melt varies depending on n, the method used to initialize the flow-law prefactor, and the sliding law, another key control on glacier velocity. We find that when models that differ in n alone are subjected to increasing melt, a land-terminating glacier on a prograde bed loses less mass with larger n while a marine-terminating glacier on a retrograde bed loses more mass with larger n. These results suggest two categories of glaciers: mass-balance-controlled, for which larger n causes less volume loss; and dynamically controlled, for which larger n causes more volume loss. Reasonable values of n can cause the mass loss of a glacier in response to changes in melt to vary by ±100% depending on the method used to initialize the prefactor, further complicating n's importance. These changes are not related to the value of n in a simple way.

This study adds to several recent efforts that have explored the effect of the uncertainty in n on the behavior of the ice sheets, but is the first to explore how calibrations of the prefactor affect are likely to affect uncertainty in projections in practice. Our results suggest that consideration of how A is initialized, and more reliable calibrations of A, are essential to understand the uncertainty that n introduces to projections of ice-sheet behavior.

Offshore Characterization of the Amundsen Sea Embayment Geologic Environment

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Understanding the sub-ice-sheet environment and the interactions between the ocean, ice, and solid Earth systems is essential for improving future projections and past reconstructions of Antarctic Ice Sheet stability and sea-level rise. The geology beneath ice sheets and ice shelves plays a critical role in controlling ice flow through its influence on bed topography shape, heat flux, and water distribution. Seismic profiles from the continental shelf provide constraints on the depth to the acoustic basement in the Amundsen Sea embayment, but their interpretation carries significant uncertainty. Here we present a 3D model of the offshore Amundsen Sea embayment continental-shelf-geologic environment from compiled sediment thickness, seismic, and potential fields datasets. This model characterizes the geophysical signature of basement rock in the region and provides insight into the interpretation of basement structures beneath the present-day ice sheet.

Ice Fracture, not firn fracture: Quantifying crack propagation through ice at a blue ice zone

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The strength of glacier ice is critical in understanding glacier and ice-sheet response to climate change and quantifying future sea-level rise. However, determining mechanical constraints on the yielding of glacier ice in a natural setting is a challenging task, with current estimates generated primarily through experimental and theoretical frameworks. Here, we derive a multiyear time series of surface velocity, deformation, and fracture patterns on Shirase Glacier, a blue ice area with minimal snow or firn coverage. This setting offers a unique opportunity to observe and quantify large-scale fracture processes on exposed glacier ice rather than fractures obscured by a firn column. We used Sentinel-1 synthetic aperture radar (SAR) feature tracking to generate surface displacement and derive strain rates over monthly intervals from 2015 to 2023. By tracking the evolution of deformation and fracture propagation in a Lagrangian reference frame, we assess the morphological evolution of fractures as ice advects towards the calving front. The time-dependent nature of our dataset reveals patterns of crack propagation consistent with fracture mechanics theory. Our results highlight the spatial and temporal variability of surface stress and crevassing in a marine-terminating system. In addition to advancing process-level understanding of the dynamics of glacier ice, our work showcases open-source and cloud-compatible processing framework for analyzing high-resolution SAR datasets at scale.

The impact of regional-scale upper-mantle heterogeneity on glacial isostatic adjustment in West Antarctica

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West Antarctica is underlain by a laterally heterogenous upper mantle, with localized regions of mantle viscosity reaching several orders of magnitude below the global average. Accounting for 3-D viscosity variability in glacial isostatic adjustment (GIA) simulations has been shown to impact the predicted spatial rates and patterns of crustal deformation, geoid, and sea level changes in response to surface ice loading changes. Uncertainty in the viscoelastic structure of the solid Earth remains a major limitation in GIA modeling. To date, investigations of the impact of 3-D Earth structure on GIA have adopted solid Earth viscoelastic models based on global- and continental-scale seismic imaging, with variability at spatial length scales >150 km. However, regional body-wave tomography shows mantle structure variability at smaller length scales (∼50–100 km) in central West Antarctica. Here, we investigate the effects of incorporating smaller-scale lateral variability in upper-mantle viscosity into 3-D GIA simulations. Lateral variability in upper-mantle structure at the glacial drainage basin scale is found to impact GIA model predictions for modern and projected ice mass changes, especially in coastal regions that undergo rapid ice mass loss. Differences between simulations adopting upper-mantle viscosity structure inferred from regional- versus coarser continental-scale seismic imaging are large enough to impact the interpretation of crustal motion observations and reach up to ∼15 % of the total predicted sea level change during the instrumental record. Incorporating a strong transition from lower viscosities at the mouth of the Thwaites and Pine Island glaciers to higher viscosities in the interior of the glacier basins results in a ∼10%–20% difference in predicted sea level change in the vicinity of the grounding line over the next ∼300 years. These findings have a range of implications for the interpretation of geophysical observables and improving constraints on feedbacks between the West Antarctic Ice Sheet and the solid Earth.

Mapping Antarctic geological trends via geostatistical roughness analysis

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Subglacial geological conditions strongly influence the dynamics and stability of the Antarctic Ice Sheet. Topographic roughness offers insight into these conditions, but quantifying roughness is challenging due to the sparse and irregular distribution of radar bed measurements. Here we use variogram analysis, a geostatistical tool that quantifies spatial covariance, to quantify bed roughness across Antarctica. We perform a moving window variogram analysis to produce maps of continent-wide roughness and geostatistical parameters. We apply clustering techniques to the roughness and elevation information, which exposes regional patterns in basal conditions including the identification of plausible sedimentary basins. These roughness-derived data products could be used to initialize the basal friction coefficient or inform the selection of sliding laws for ice-sheet modeling experiments.

The Polar Rock Repository: furthering knowledge of the Antarctic ice sheet using legacy collections

Erica Maletic[1], Dr. Anne Grunow[1]
[1]Polar Rock Repository

The Polar Rock Repository (PRR) is a United States National Science Foundation funded facility that provides online access to rock samples, unconsolidated deposits, terrestrial cores, and dredge samples for scientific research. The use of existing legacy samples and metadata from remote regions offers scientists the ability to expand the scientific and geographic scope of their research. The PRR online database (prr.osu.edu) includes a wealth of metadata on all 65,000+ samples, including field notes, sample photos, information on logistics, stratigraphy, observed minerals (e.g., olivine, garnet, anorthoclase), and surface features that can be useful to a broad range of earth scientists. Many samples also have orientation data that has been beneficial in cosmogenic studies.

The PRR has also created a media archive of ~9,000 images (with some dating back over 60 years) that can provide glaciological, geological, and logistical information as well as provide a record of temporal change associated with surface features (snow cover, ponds, icebergs, streams, lichen, etc.). By making terrestrial and marine geological materials available to the cryosphere community, the PRR represents an invaluable resource to help answer key questions involving ice sheet-ocean interactions and the processes affecting glacial retreat. The PRR website (prr.osu.edu) provides multi-field searchable criteria, enabling researchers to filter samples relevant to their interests.

Environmental, geophysical, and glaciological researchers have used PRR legacy samples, including but not limited to:

1. Subglacial precipitates
2. Pedogenic calcite – weathering salts
3. Coral/marine invertebrates on dredge clasts
4. Lichen, moss, and soil residues on terrestrial samples
5. Fe-Mn nodules and surface staining (e.g., Fe-oxide, Mn-oxide)
6. Glacial surface features (e.g., striations, facets, polish) and erratics
7. Microbial communities in archived soils

Antarctic Ice Sheet questions that have been addressed using PRR samples/metadata include:

- Millennial scale climate cycles in the East Antarctic ice sheet since the Pleistocene have been documented using U-series methods on subglacial precipitates.
- Timing of glacial reconstructions using cosmogenic nuclides and optically stimulated luminescence studies.
- Provenance studies suggesting sea-level oscillations in the early Neogene could be from a large West Antarctic Ice Sheet.
- Paleotemperature proxies using coral found on dredge samples in the Ross Sea and Southern Ocean.
- Landscape evolution studies related to the onset of glaciation.
- CO2 fluxing and magma transport studies using volcanic samples from Mt. Erebus.
- Use of Fe-Mn nodules to assess incursions from the Antarctic Ice Sheet.
- Variability in the strength of the earth's magnetic field using paleomagnetism

Nonlinear longitudinal stress coupling in glacier and ice sheet flow

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The West Antarctic Ice sheet exhibits high variability in flow speed, over multiple orders of magnitude. Slow flowing interior ice is well-described by the Shallow Ice Approximation, which assumes that velocity is only a function of local driving stress. By contrast, faster flow in ice streams, marine terminating glaciers, and ice shelves is better described by the Shallow Shelf/Shelfy-Stream Approximation (SSA), which requires a nonlocal balance between driving stress, friction at the ice-bed interface, and longitudinal/membrane stresses. Nonlocal stresses mediate spatial variability in ice flow, over a finite length scale, known as the longitudinal coupling length (LCL), which determines how far viscous stresses may be transmitted in glaciers and ice sheets. The strongly nonlinear rheology of ice complicates the stress transmission, but previous work has relied on either linear-Newtonian models or linearized, small-perturbation models, to determine the LCL. Here, we derive new exact solutions to SSA, which explain how nonlinear feedbacks between the stress state and the nonlinear rheology of ice determine the LCL. For complex and multi-scale flow fields, these exact solutions provide a foundation for an approximate semi-analytic model, which can reconstruct the effects of a nonlocal stress balance, given input data for the driving stress and friction fields, with surprising accuracy. Unravelling the dependence of the LCL on nonlinear processes helps us understand processes at ice sheet grounding lines, subglacial lakes, ice stream shear margins, and more. We anticipate this work to be a starting point for a variety of analytic and numerical approaches, aimed at determining the response of the Greenland and Antarctic ice sheets to climatic forcings.

Quantifying Firn Processes in Antarctica Using Radar–Laser Altimetry Bias

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Across the Antarctic Ice Sheet (AIS), net accumulation from snowfall is the only non-negligible input to the mass balance (MB) equation. It is estimated to be about 2300 Gt annually, equivalent to 6 mm/a of sea level decline. As old snow, or firn, becomes buried by newly fallen snow, its density increases with depth until it is compacted into glacier ice at ~830 kg/m³. Understanding the firn column's time-varying density is essential for converting changes in ice-sheet volume, measured by satellite altimetry, into changes in ice-sheet mass. This common method of assessing ice-sheet mass balance uses numerical models to estimate firn-density change, but these can be biased both by the climate model driving the firn model and inherent assumptions of the firn models. To improve our understanding of firn densification processes, we can leverage the penetration of satellite altimeter signals into the snowpack, which is a function of snow properties including firn density. ICESat-2 laser altimetry uses a green laser (532 nm), leading to a snowpack penetration of 1s to 10s of cm, whereas CryoSat-2 radar altimetry uses Ku-band radar (2.2 cm), which is also sensitive to subsurface properties and can penetrate the snowpack up to 1-1.5 m. Ultimately, this differential snowpack penetration leads to a bias between satellite altimeter observations, which can then be related to firn densification and its variation spatially and temporally. Here, we compare CryoSat-2 elevations, ICESat-2 elevations, and Global Navigation Satellite System (GNSS) records at 60 locations across the West Antarctic Ice Sheet (WAIS). Using CryoSat-2 and ICESat-2 elevations estimated at the location of the GNSS site, we generate both an absolute (compared to GNSS) and a differential bias time series for each location. We use the resulting bias time series to analyze the spatial and temporal variability of firn density in the region. Although we initially assess these biases where we have in situ ground truth, we can scale our results using the six years of overlap between the CryoSat-2 and ICESat-2 missions to ultimately improve our surface mass balance (SMB) estimates at the continental scale in an effort to more precisely predict and prepare for future coastal change.

Deep Learning Insights into Geological and Glaciological Controls on Antarctic Basal Friction

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Predicting how much Antarctica's ice sheet will contribute to future sea-level rise is challenging because we do not fully understand what controls how easily glaciers slide over the ground beneath them. In ice-sheet models, this "slipperiness" is often tuned to match observations, but it is unclear which physical characteristics most strongly influence it.

We combined physics-based ice-flow modeling with deep learning to see whether we could learn general rules linking measurable glaciological and geological features to the basal friction coefficient — a key parameter that controls sliding — and then use those rules to predict friction in places we did not train on. We focused on three glacier systems in the Amundsen Sea Embayment: Pine Island, Thwaites, and the Dotson–Crosson region. First, we used an inverse modeling approach to estimate the spatial pattern of basal friction needed for our ice-flow model to reproduce observed surface speeds. Then we trained neural networks to relate this friction field to features like ice geometry and slopes, bed elevation and roughness, surface temperature, geothermal heat flux, and gravity-based indicators of subsurface geology. Finally, we tested whether these learned relationships could be applied to other glaciers by embedding them back into the ice-flow model and checking how well they reproduced observed velocities.

We found that neural networks can capture complex, nonlinear relationships between features and basal friction and that combining a range of glaciological and geological variables generally improved performance. However, what we learned in one glacier rarely transferred with the same effectiveness to another. Models trained with data from Pine Island Glacier often generalized better than those trained with Thwaites Glacier or Dotson Ice Shelf catchment alone, but none of our models worked equally well across all three systems. The fast-flowing trunk of Thwaites — marked by very low friction — was especially hard to predict unless Thwaites itself was included in training, suggesting that important processes there are not well represented in our current feature set and/or resolution.

These results tell us that the relationship between basal friction and the measurable properties of ice and bedrock varies in space, shaped by a complex mix of bed geology, heat, water, and ice dynamics. This limits how well purely local, point-by-point feature–friction mappings can be transferred from one glacier to another. Future progress will likely require adding missing variables (e.g., subglacial hydrology and sediment properties), using features that capture upstream or non-local effects, and grouping training data by shared physical regimes rather than just by glacier boundaries. While not a drop-in replacement for physical sliding laws, our hybrid inversion-plus-learning approach helps reveal where data-driven methods can usefully augment ice-flow models and where gaps in physics or data still hold back reliable predictions.

Development of MITgcm ECCO-downscaled Amundsen-Bellingshausen Sea regional simulation

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The Amundsen and Bellingshausen Seas (ABS) are among the most rapidly changing regions of the Southern Ocean, playing a central role in Antarctic ice-shelf mass loss and global sea-level rise. To investigate the processes driving these changes, we developed a high-resolution regional ocean model based on the MITgcm, downscaled from the global ECCO LLC270 ocean state estimate and further optimized with regional observations. The configuration is extensively evaluated against hydrographic, mooring, and satellite datasets, capturing key features of the mean state, seasonal cycle, and interannual variability. Simulated temperature–salinity profiles and water-mass distributions align closely with CTD and mooring observations, while sea-ice concentration, extent, and polynya variability agree well with satellite records. Modeled ice-shelf basal melt rates fall within observational ranges and reproduce spatial patterns consistent with known ocean access pathways. The configuration also includes passive tracers for surface water, ice-shelf meltwater, and Circumpolar Deep Water, as well as Lagrangian particle tracking, enabling detailed studies of water-mass transformation and tracer pathways. We present recent applications of this model in high-impact studies and make the full configuration—including code, diagnostics, tracer outputs, and sensitivity simulations—openly available. By doing so, we aim to provide a community resource that supports cross-disciplinary research, advances data interpretation, and guides future observations in the ABS region.

Open Polar Radar Tomographic Swath and Multipass Synthetic Aperture Radar Processing Assessment

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Open Polar Radar (OPR) is a multi-institution organization whose focus is to provide unified data processing tools, products, and access for over 3.5 million line-km of radar sounder data. As part of OPR, we assess two advanced processing techniques, tomographic swath processing and multipass differential interferometry, that are part of the OPR open-source toolbox. Cold Regions Exploration (COLDEX) recently collected data over the Ross Ice Shelf with a 22-element array spread over an aperture 57 wavelengths in length. This large aperture provides excellent resolution which can be used to assess the array performance of smaller arrays by processing with subsets of the full 22-element array. We compare different combinations of the 22-element array in complex and in simple topography to show how the resolution (main lobe width) and automated tracking varies for different array configurations and scenes. The purpose is to show the thresholds between regions of performance and the behavior of the algorithm under these circumstances as a function of array geometry. We also report on the multipass performance for two different radar systems, one operating at 60 MHz for COLDEX and one operating at 195 MHz for Operation IceBridge (OIB). We analyze repeat passes within the same season so that the expected relative velocity between layers should be very small. Phase errors with and without spatial baseline correction using cross-track slope estimates from 3D imaging are also compared.

Sensitivity of the West Antarctic Ice Sheet to 2° Celsius of Warming: The SWAIS2C project

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We present an overview of the SWAIS2C project. The project aims to unravel past and present factors influencing WAIS dynamics in response to warmer temperatures. SWAIS2C targets two sites, chosen to obtain geological data close to the centre of the WAIS to improve model-based projections of future sea level contributions from Antarctica. The first site (KIS3) is close to the grounding line of the Kamb Ice Stream and sensitive to ocean forcing of ice shelf and ice sheet collapse. The second site on the Crary Ice Rise (CIR) demarks a pinning point of the ice shelf and offers a complementary view on processes that can (de)stabilize the WAIS.

In the first two field seasons of the SWAIS2C project in 2023/24 and 2024/25 hot water drilling was successfully completed in both years and penetrated more than 580 m of ice to provide access to the ocean cavity and seafloor. Oceanographic measurements were taken in the ~55 m ocean cavity beneath the ice shelf, together with videos of the seafloor and ice shelf and installation of a long-term oceanographic mooring. Gravity and hammer coring during both seasons yielded at total of 9.5 m of sediment, including the longest sediment core from the Siple Cost, measuring 1.92 m. All of the cored material was X-rayed in the field. During each year, several cores were extruded in a sterile environment and sampled for microbiology, geochemistry, pore waters and ancient DNA work.

Deep drilling was attempted in both years using the Antarctic Intermediate Depth Drill (AIDD). After deploying 450 m of drill string this past season, we had to call off operations, just a couple of hours short of retrieving our first sediment core. Since out last field season, we undertook an external review and as a result the AIDD system was modified and test drilling operations were completed in New Zealand in preparation for our next drilling attempt at CIR in 2025/26. At CIR we hope to recover 200 m of sediment core and perform a range of geophysical surveys. CIR is an area of grounded ice frozen at the bed within the Ross Ice Shelf that is thought to have stabilized around ~1400 AD. Recent geophysical surverys indicated the underlying sediment consists of Holocene grounding zone wedge sediments that unconformably overlie gently dipping strata hypothesized to be of Neogene age. This hypothesis is based on the recovery of reworked diatoms at CIR during hotwater drilling efforts in the 1980s and is consistent with gravity core sediment recovered during the Ross Ice Shelf Project (RISP) at Site J-9, implying records of episodic open marine conditions during the Neogene.

Deep field work in Antarctica is challenging, but the questions we are trying to answer for humanity are worth it. By addressing the challenges we have faced in our prior seasons, our project hopes to provide a proven drilling system that will be capable for future use, and build international collaborations to target drilling sites that can help us better determine the future of the WAIS.

Past and Future Retreat of Thwaites Glacier: Sensitivity, Calibration, and Sea Level Rise Projections

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Modeling Antarctica's contribution to sea level rise requires accurately reproducing the recent observational record—something current ice sheet models have struggled to achieve. Here, we present a high-resolution simulation of Thwaites Glacier, West Antarctica, over the past 25 years and into the future using the Ice Sheet and Sea Level System Model (ISSM). Key model improvements include: 1) a reconstruction of the historical state of the glacier system by configuring the ice sheet model with conditions representative of the 1990s when the glacier was near mass balance and 2) a kilometer-scale seawater intrusion parameterization beneath grounded ice, associated with strong submarine melt at the grounding zone. We quantify the hindcast model ensemble by accounting for sensitivities to grounding zone width and seawater-driven melt rates within the grounding zone during the observed glacier retreat from 1996 to 2021, using a Bayesian calibration approach. Simulations without grounding zone melt fail to match the historical observed retreat. On the other hand, including kilometer-scale grounding zone melt helps to reproduce the past 25 years retreat, glacier speed-up, and thinning, especially along Thwaites' fast-moving main trunk, though retreat is over-predicted on its slower eastern flank. Using this setup to project the next 100 years, we find continued sea level contributions, but retreat in the main trunk is temporarily restrained by Mouginot Ridge, a 300 m high bedrock feature. Such enhanced models improve sensitivity to ocean forcing and could potentially double Antarctica's projected sea level rise contributions.

Piecing together the evolution of ice shelf rift mélange with multi-sensor satellite observations

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Mass loss from Antarctica at its outlet glaciers has been contributing to global sea level rise since the 1990s, but projections are deeply uncertain due to a paucity of observations of key driving processes. Floating ice shelves regulate this flow of grounded ice into the ocean through compressive buttressing forces that are generated when they contact pinning points and embayment margins. Changing environmental conditions can drive an ice shelf away from steady-state by modifying basal melt rates and/or the forces responsible for fracture and rift development. One under-observed control on rift development is infilling mélange, which is a heterogeneous mixture of meteoric ice debris eroded from rift walls, sea ice, blown snow and basal marine ice. By exerting either resistive or wedging forces, accumulated mélange can contribute to the timing and trajectory of fracture development. However, documenting the concurrent evolution of fractures, rifts and mélange requires years to decades of high-resolution observations in three dimensions with near-complete spatial coverage and vertical accuracy; something no single sensor can achieve. Here, we produce altimetry-registered digital elevation models (DEMs) of ice shelf rifts and infilling mélange from 2018 to the present by leveraging the high vertical accuracy of NASA's ICESat-2 laser altimetry with the high lateral resolution of DEM strips derived from Maxar WorldView stereographic optical imagery by the Polar Geospatial Center. We show that mélange thickness estimated from its freeboard can vary by over 100 m, and that mélange surface expressions vary across different ice shelves. The spatial and temporal variability of mélange provides information on its evolution and potential sensitivity to environmental conditions. Ultimately, improved observations across a range of Antarctic ice shelf rifts provide glimpses into the life cycle of mélange, and should contribute to our understanding of how mélange affects ice shelf rifting dynamics and changes in buttressing of grounded ice.

Duration versus dates – how can geochronology provide better constraints for ice dynamics models?

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When and how Antarctic glaciers responded to the last natural warming event, after the Last Glacial Maximum, is of primary importance to forecasting how they will respond to current warming. Marine geological approaches to these questions typically involve dating grounding zone wedges and down-core signatures of grounding line extent, whereas glaciologists adeptly date the last exposures of rocks on land and on the ice. Ultimately, this information can be ingested by numeric models of varying complexity to constrain key questions about ice-climate dynamics, with well-placed time constraints for ice extent and thickness being critical. Recent modeling work, however, has sought to improve the utility of singular dates as time constraints, showing the utility of the duration of ice position is far greater. The modeling community seems to be responding favorably. Observation of duration has always been difficult, but with some simple assumptions, ion concentration profiles of subglacial sediment porewaters and diffusion of carbon might be able to provide such estimates. Such measurements are far and few between, and the associated assumptions are largely untested. Here, we assess these assumptions with data from the Subglacial Antarctic Lakes Scientific Access (SALSA) project to refine this approach. Differences and similarities between ice retreat durations along the Siple Coast allow us to discern where such models of duration can be maximized for glaciological modelers, and what measurements and assumptions can be improved.

On the Inaccessibility of US Subglacial Access Drills

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Among the top priorities of the international Antarctic science community is accessing deep ice environments, from grounding zones sensitive to climate change to subglacial lakes where unexplored ecosystems thrive to subglacial records of past climate. Frontier challenges like these require focused development not always achievable by individual science programs. This is particularly critical in Antarctica since capital to develop community resources is limited and key design choices can place logistical restrictions on future science and resource allocation, leading to growing cost or missed opportunity. Within the US, the science community has advocated for hot water access drills (HWDs) to enable our most critical science questions for more than a decade to NSF, USAP and the ice drilling program: such HWDs are needed to meet Priorities I and II outlined in the 2015 US National Academy of Sciences decadal survey and the 2021 review. And yet no progress has been made on this front.

The current state of the art and most established HWD systems for subglacial access are designed, built and operated by the British Antarctic Survey. While the US was an early lead in access drilling, and HWDs from the US arsenal established key capabilities required for science, such critical assets are either in disrepair or lack needed agility and scalability needed to reach the vast majority of science targets and bring USAP into the next generation of sub-ice science. The US program is currently lagging far behind the international community (UK, New Zealand, Korea, Australia and China) in mobile access drilling and no US-based drilling asset exists that enables the most compelling science as defined by the National Academies and community priority documents.

Here we advocate again for the development of a US Access drill capability and describe progress in designing such a system. Polar-ADELIES is a hot water drill concept leveraging heritage designs from the British Antarctic Survey and WISSARD programs to enable smart, clean, deep access drilling to achieve interdisciplinary science. Polar-ADELIES would enable flexible power, communications, and other interfaces (for example with winches and terminations) to monitor borehole conditions for drilling and science. The interdisciplinary science goals of the polar community require a range of in situ and ex situ physical and biogeochemical measurements, some of which could be deployed and monitored through the drilling interface, including: hydrography, water sampling (~1-10L at discrete depths), in situ water filtration systems to concentrate particulates and cells, and subglacial sediment sampling via wireline coring. Deployment of cameras and underwater platforms and vehicles is a frontier that will be enabled. Developing such a drill along with our international partners would enable the US to contribute cutting edge technological advancements to hot water drilling and leverage BAS and other programmatic heritage, helping reduce both cost and risk of drilling operations.

Basal Ice Under Thwaites Glacier: Windows into Subglacial Processes?

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Processes proximal to ice shelf and glacier grounding lines affect everything from ice loss to basal sliding to nutrient availability in the sub-ice ocean, thus connecting oceanographic, glaciological and hydrological process across the grounding line is important. We performed the first robotic exploration of the grounding zone of Thwaites Glacier with underwater vehicle Icefin in early 2020 as part of the International Thwaites Glacier Collaboration. These in situ observations extended from the grounding line over two ~3km transects towards the ocean and included hydrographic, bathymetric, sonar and imaging of conditions from the bed to the ice base including within crevasses. The novel observations made in this environment include imagery and forward looking sonar of the ice base collocated with hydrographic data that might enable understanding the influence of basal ice melting within the Thwaites ocean cavity and the source of the basal ice. The Icefin imagery revealed a diverse set of basal ice conditions, with complex geometry, including a range of terraced features, smooth ablated surfaces, crevassing, sediment rich layers of varying characteristics with a range of stratigraphic relationships with each other and with glacial ice, as well as interspersed clear or discolored ice absent of obvious sediment. The distribution of these basal ice types varies with distance from the grounding line. Sediments along the sea floor range from mixtures of course angular gravel near the grounding zone distributed between larger boulders to fine grained downstream. We observed material in the ice that ranged from fine grained sediment layers compressed within the ice to small angular particles volumetrically distributed within ice, to gravel and cobbles, as well as trapped boulders up to meter scale. We observed active melting out of these materials from the ice, offering potential constraints on sedimentation resulting from melting. The ocean directly beneath the ice varies spatially, from turbid and moderately well-mixed near the grounding zone to highly stratified within terraces, and we have previously reported signatures of mixing between the ocean, glacial meltwater, and subglacial water from observations of changing temperature, salinity and dissolved oxygen. Here we further investigate the distribution of basal ice and spatially-resolved observations of the ocean to investigate the provenance of these features. We investigate spatial variability in the salinity and dissolved oxygen below varying basal ice to explore the potential contribution of melting basal ice to the local environment, and possible evidence for upstream accretion of subglacial fresh water.

Stochastic inversion for subglacial topography: a case study of Pine Island Glacier

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Predicting the future of the Antarctic Ice Sheet requires an improved understanding of the subglacial topography and its associated uncertainties. Subglacial topography, which is primarily measured by airborne ice-penetrating radar, has measurement gaps of 10’s or more kilometers. Mass conservation inversions are often used to obtain gridded topography maps in the rapidly evolving regions with high-velocity ice flow. However, the typical optimization approach produces one topography map that is much smoother compared to the topography observed by the radar data. This approach also only provides maximum error as an uncertainty estimate, where a robust uncertainty quantification requires presenting the full distribution of subglacial topography.

Markov chain Monte Carlo (MCMC) can be used to infer the distribution of subglacial topography from mass conservation, which has generated subglacial topography realizations that are compatible with mass conservation and have realistic roughness. However, MCMC is computationally expensive and cannot be parallelized. In addition, the number of iterations required for convergence is difficult to assess. In this study, we utilize an alternative method called probabilistic linear Gaussian inversion (LGI) to solve for subglacial topography. LGI reconstructs topography realizations with realistic roughness and minimizes the misfits to mass conservation. In addition, it directly provides both the bed elevation distribution and an approach to generate individual subglacial topography realizations. We demonstrate the application of the LGI to Pine Island Glacier, compare the results with those from the MCMC method, and discuss its potential for efficiently quantifying the impact of subglacial topography uncertainty on ice sheet model predictions.

Ice-sheet mass balance from satellite altimetry-gravimetry fusion precisely quantifies atmospheric and dynamic signatures of change

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Global ice mass loss is the largest contributor to modern sea-level rise; however, its future contribution remains highly uncertain given our limited understanding of the mechanisms that drive change. Furthermore, identification of regional ice mass changes is critical for precise quantification of spatially varying global sea-level change. Therefore, knowledge of regional signatures of major drivers may prove useful for understanding ice sheets' role in future sea-level changes. Here, we present a novel approach fusing satellite gravimetry (GRACE-FO) and altimetry (ICESat-2) observations using existing surface-process models to better constrain poorly understood processes like firn densification and provide the first observationally constrained partitioning of ice mass change into surface mass balance (SMB) and ice dynamics. We generate spatial fingerprints of SMB and firn air content variability through empirical orthogonal function analysis, then invert for their associated principal components using monthly GRACE-FO mass and ICESat-2 volume measurements as observational constraints (December 2018-December 2024). This fusion approach reconciles altimetric and gravimetric mass estimates while enabling high spatial resolution attribution of change drivers. We show Greenland Ice Sheet mass lost at 176.6 ± 16.3 Gt y^{-1}, substantially less than previous estimates, with 76% attributed to SMB and 22% to ice dynamics. Most remarkably, Antarctica exhibited near-zero mass trend (21.7 ± 21.7 Gt y^{-1}) compared to recent losses of -115 ± 55 Gt y^{-1}, driven by exceptional snowfall during 2020-2022. However, dynamical mass losses from Pine Island and Thwaites continue at a high rate, contributing 170.8 ± 6.0 Gt y^{-1} to losses. Much of the dynamic losses from West Antarctica were compensated by snowfall in 2022, during which 491.2 ± 33.3 Gt (over 1 mm of sea level fall) accumulated across the entire ice sheet. This joint observational approach demonstrates that short-term variability is entirely atmospheric driven while dynamic losses remain constant in the observational record.

Apparent post-drainage refilling of subglacial lake Cook-E2 explained by high-resolution ice-flow modeling

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The 2006-08 drainage of subglacial lake CookE2 was one of the largest episodic movements of subglacial water observed to date. The discharge released an estimated 2.7 km^3 of water and left a ~70-m deep depression in the ice sheet surface. Since the main lake drainage event, the bottom of the depression has been rising slowly with a peak rate of around 1 m/yr (Moon et al, 2017). Recent studies (e.g. Malczyk et al, 2023, Moon et al, 2022, Li et all, 2020) about the post-drainage behavior of the lake have included speculations about sources of water that might contribute to the lake's refilling. The lake, however, is very close to the upstream hydrological divide in a region where basal melt rates are thought to be small, so estimates of water produced in the area that might drain into the lake appear to be too small to explain the observed surface uplift. In this presentation, we present updated observations of the basin geometry and uplift rate, and use snow radar measurements to map snow accumulation anomalies. We then make a comprehensive analysis of the different mechanisms that might contribute to surface change over the lake, including high-resolution modeling of basal hydrology and ice dynamics. We demonstrate that flow of basal water is unlikely to produce significant surface-height change, and that snow-accumulation anomalies associated with the depression in the ice-sheet surface account for only a small fraction of the observed change. Instead, we find that the surface-height change is best explained by ice flow driven by the surface slope of the depression. Our full-Stokes three-dimensional ice-flow model produces uplift rates at the center of the basin that are 1-2 times the observed rate, depending on assumptions about basal drag and ice rigidity. In keeping with previous modeling (e.g. Sergienko et al, 2007, Stubblefield et al, 2023), this work demonstrates that water flow is not the only contributor to surface-height changes during and after subglacial lake drainages, and that the feedback between surface-height changes and ice flow needs to be taken into account when interpreting surface height changes.

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West Antarctic elevation history as a constraint on ice-sheet model physics

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Reconstructions of the topography of the ice sheets during the past (e.g., last interglacial, last glacial maximum (LGM)) are routinely used as boundary conditions for paleoclimate simulations with earth system models. The ice-sheet modeling community's work is relied upon for these reconstructions. To accomplish this, ice-sheet modelers rely on a combination of modern measurements of present-day geometry and velocity, and bed topography and geological constraints on past ice extent and thickness (e.g., Lecavalier and Tarasov, 2025, https://doi.org/10.5194/tc-19-919-2025). Because of the uncertainties in ice-sheet model parameters, it is standard practice to tune these models using scoring metrics; these are generally weighted towards modern conditions, which have the smallest uncertainties (see e.g., Pollard et al., 2026 https://doi.org/10.5194/gmd-9-1697-2016, Albrecht et al. 2020 https://doi.org/10.5194/tc-14-633-2020). Ice-sheet elevations from the interior of the ice sheet have generally not been used, because they are considered too uncertain. This understandable! Published estimates of the LGM ice elevation in the WAIS interior vary by hundreds to more than 1000 meters between early estimates from geodetic measurements with glacioisostatic models (Ice4G, Ice5G, etc.) and the estimates from analysis of ice cores (e.g. Werner et al., 2018, Buizert et al., 2021).

We argue that these elevation histories can be known better, and are important because they place quite strong constrains on a key ice-sheet model parameter, the basal traction or "critical till angle") in areas where the ice sheet expanded (e.g., in the Ross Sea when it was grounded there). This parameter cannot be obtained from inversion of modern velocity data, since the ice sheet is no longer grounded there. Yet "reasonable" values vary by three orders of magnitude, with major implications not only for past ice sheet reconstructions, but also the spin-up of ice sheet models, and therefore for future projections as well.

We show in Markle and Steig (in review, PNAS) that most previous geodetic/glacioisostatic and ice-core based estimates of ice elevation at the LGM and Holocene are inconsistent with strong constraints on ice sheet surface temperature history. Moreover, ice-sheet models that use the known accumulation history from the WAIS Divide ice core are in excellent agreement with our results, in contrast with those that use accumulation histories derived from large-scale climate variations (i.e., from ocean sediment cores or East Antarctic ice core records, both of which are common). Critically, both the timing and magnitude of the LGM minimum elevation, and the early Holocene maximum elevation, provide a constraint on the basal traction. From examination of the Albrecht et al. and Pollard et al. ensembles tends, we find the the best values of the basal parameter to be on the low end (i.e., a slippery bed), which also tends to provide the best results for matching modern ice sheet conditions.

Development of an ICESat-2 land ice mass change product

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The laser altimeter aboard NASA's ICESat-2 satellite measures ice-sheet elevation change with centimeter-scale resolution, and the ICESat-2 ATL15 data product provides gridded elevation changes at quarterly temporal resolution. Using these volume-change measurements to calculate mass changes requires knowledge of how snow accumulation, firn compaction, and solid-earth processes affect the elevation. At present, researchers who require ice-sheet mass change data must make the volume-to-mass conversion themselves, which requires (1) running a firn-densification model or locating extant firn-model outputs and (2) appropriately applying a solid-earth correction to the ICESat-2 data. Recognizing that many research teams desire mass-change rather than elevation-change data, and that the volume-to-mass conversion can present a barrier to calculating mass change, we are developing an ICESat-2 mass change product to accompany the gridded height changes. Here, we present details about the effort and show initial results. We have run the Community Firn Model (CFM), forced with data from NASA's MERRA-2 climate reanalysis, on the ATL15 10-km grid to simulate evolution of firn air content (FAC) across the Antarctic and Greenland Ice Sheets. We apply the FAC correction to ATL15 to provide an initial estimate of the quarterly mass change. Ongoing work includes applying the solid-earth correction, automating the workflow for future updates, and uncertainty quantification.

Glacier-Mélange Feedbacks as a Stabilization Mechanism for Classical Marine Ice Sheet Stability

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Ice mélange, a mixture of icebergs, sea ice, and brash ice, often occurs at the terminus of marine-terminating glaciers. When present, ice mélange has been shown to moderate glacial calving rates through a buttressing effect, where periods of reduced calving and terminus advance correlate with the presence of rigid mélange for many of the largest outlet glaciers of Greenland. This observation suggests that mélange can act as a stabilization mechanism against glacial retreat. Additionally, increased calving leads to higher mass flux which can promote growth of the ice mélange. This coupled feedback presents a potential stabilization mechanism against rapid glacial retreat of outlet glaciers, particularly those in narrow fjords or those that may soon retreat into narrow fjords.

Here we extend a 1D continuum mélange model and a parameterized glacier calving law to investigate how the classic marine ice sheet instability can be stabilized by the presence of an ice mélange. We find that ice mélange can stabilize glaciers on reverse sloping beds, but only for certain ranges of parameter space, with stability depending strongly on the calving law and fjord width. We further implement a novel coupled mélange-ocean-glacier model utilizing the same mélange model and a 3D ocean model (MITgcm). Using this model, we investigate the potential for ice mélange to act as a stabilizing mechanism subject to more realistic ocean conditions. We find that warm water at depth sets an upper bound on mélange size, which limits the maximum buttressing effect of ice mélange.

Where the Ice Meets the Sea: Sub-Ice-Shelf Tides and Grounding Zones with ICESat-2

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Antarctic ice shelves occupy 75% of the Antarctic coastline and 10% of the total ice-covered area. They are partitioned from the grounded ice sheet by the "grounding zones", regions typically a few ice thicknesses wide where the ice first goes afloat. Most regions of the ice shelves outside the grounding zones are in hydrostatic equilibrium, and are responsive to variations in sea surface height due to e.g. tides, dynamic topography, and the inverse barometer effect (IBE). Variations in ice shelf height can be directly measured using laser altimetry measurements from NASA's Ice Cloud and land Elevation Satellite (ICESat) and its successor mission (ICESat-2). ICESat-2 samples 1387 unique reference ground tracks that are precisely repeated in polar regions every 91 days. Although a 91-day repeat sampling is long compared to the frequencies of most tidal constituents, the elevation data does provide a precise estimate of the local tidal signal in both hydrostatic and amplitude-modulated regions. Here, we use the ICESat-2 Slope-Corrected Land Ice Height Time Series product (ATL11) along with tidal constants provided by the Circum-Antarctic Tidal Simulation (CAT2008) to estimate the present-day locations of the grounding zone via their inland extent, and create Antarctic-wide maps of ice flexure. Ongoing work includes improving the efficiency of the open-source tide model driver (pyTMD), quantifying the uncertainty of each estimate, and automating the workflow for regular updates.

Reconstructing Spatial and Temporal Variability in Grounding Zone and Ice Shelf Retreat Around Ross Bank

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Understanding how the Ross Ice Shelf (RIS), a key buttress of West Antarctica, responded to past climate forcing is crucial for assessing its future stability amid ongoing change. While today's calving front is pinned at Ross and Roosevelt Islands, a recent study showed that the RIS was formerly pinned ~100 km further north at Ross Bank, a broad, shallow submarine bank. The unpinning from Ross Bank is recorded by a concentric recessional ridge pattern, which suggests a gradual stepwise grounding line retreat up the sides of this former pinning point. Heavy sediment reworking on the crest disrupts the stratigraphic record and complicates the chronology of retreat. Thus, analyzing the more complete deglacial records preserved on the flanks below 400 meters water depth is essential for reconstructions. We use integrated diatom and foraminiferal data, along with grain size and physical properties, to identify paleoenvironmental transitions in cores collected during cruises NBP2302 and NBP2403. We emphasize a reliable method of using diatom species grouped by temporal range to identify transitions between sub-ice shelf and open marine environments. This approach provides a regional stratigraphic framework for radiocarbon dating the unpinning history. Preliminary analyses reveal distinct regional differences in ice shelf retreat styles and post-glacial productivity around Ross Bank. The results also highlight localized depositional controls that demonstrate marked differences in sediment reworking and provenance in cores in close proximity at similar water depths. Diatom abundance is predictably high in open marine sediments at most core stations. Abundances are highest at the south-west end of Ross Bank and generally decrease toward the north-east, downstream end. There, the older, underlying sedimentary units actually show higher abundances, albeit dominated by extinct or long-range diatom species. Although further dating is needed, RIS retreat from Ross Bank was spatially variable and asynchronous, influenced by local factors such as bathymetry, ocean conditions, and sediment dynamics as much as broad climate drivers. Understanding this spatial variability, and its relevance to modern ice rise pinning points, is essential for improving projections of Antarctic ice shelf and marine-terminating glacier stability.

Bivalve genomes do not show evidence of a West Antarctic Ice Sheet collapse during the last interglacial

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The West Antarctic Ice Sheet (WAIS) is the primary source of uncertainties in projections of sea level rise. WAIS, which contains enough ice to raise global sea level by 3 m, rests mostly on seafloor. This produces buoyancy-driven feedbacks that can lead to the rapid loss of the ice sheet and corresponding increases in sea level. But, despite decades of research, there is no direct observational evidence whether WAIS collapses have occurred in the past. Here, we add to a new line of research into the stability of WAIS, using phylogeographic analyses of Antarctic organisms.

Since the base of WAIS lies mostly below sea level, its collapse would open a new seaway between Ross Sea and Weddell Sea – currently on separate sides of the Antarctic continent. This seaway would allow the dispersal of benthic (bottom-dwelling) organisms and an admixture of their populations between the connected areas. The evidence of such an interchange would be apparent in the evolutionary relationships of populations alive today, preserved within their genomes.

We used available genomes of the small circum-Antarctic bivalve Lissarca notorcadensis to determine if a close exchange between Ross Sea and Weddell Sea populations has occurred in the (geologically) recent past. To establish the evolutionary relationships between L. notorcadensis populations around the Antarctic, we built a maximum-likelihood phylogenetic tree from the mitochondrially encoded cytochrome c oxidase subunit 1 (COI) sequences in L. notorcadensis samples. In general, sequences group together according to their geographic proximity, but Weddell Sea and Ross Sea populations fall sister to each other. This relationship indeed shows that the populations share a geologically recent common ancestor and must have been connected at the time.

It is crucial to estimate the timing of this connection. WAIS has almost certainly collapsed since the inception of Antarctic glaciation, for example during the Pliocene (about 3 million years ago), when the climate was much warmer than today. However, if WAIS only collapsed then and has been stable since, this is very different from a more recent collapse such as during the last interglacial (115,000-130,000 years ago), when temperature and greenhouse gas levels were similar to current conditions.

To date the divergence of Ross Sea and Weddell Sea populations, we supplemented the L. notorcadensis tree with sequences from other arcoid bivalves which have a dated fossil record, allowing us to time-calibrate the tree. The 95% credible intervals for the last common ancestor of Ross Sea and Weddell Sea populations pre-dated 3 Ma for all clock models, and the last common ancestors of each population pre-dated 0.75 Ma. This timing shows no evidence of a WAIS collapse during the last interglacial (and possibly all of Pleistocene). While it does not exclude the possibility of a WAIS retreat during that time, it argues against a collapse of sufficient magnitude and duration to connect the Ross Sea and Weddell Sea and allow the resident populations of L. notorcadensis to remix.

FAIR enough: Encouraging best practices for data sharing at USAP-DC

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The United States Antarctic Program Data Center (USAP-DC) is a National Science Foundation supported data hub and repository for any data products collected or created as part of the US Antarctic Program. We provide support for researchers at all stages of the data lifecycle, providing an archive and metadata center for datasets created through all kinds of investigation (e.g. field, lab, model-based) and an interface for data discovery.

Availability and findability of existing data are key for open, reproducible science; enabling data comparison and compilations; and, for analyses of historical developments. This is especially true for polar regions, where logistical challenges and rapid changing environments often result in unique datasets.

We present an overview of the USAP-DC with a focus on recent efforts to assist researchers in preserving valuable Antarctic data by making it Findable, Accessible, Interoperable, and Reusable (FAIR). We include an introduction of the “FAIR scores” associated with new data submissions to USAP-DC and give guidance on best practices for preparing datasets to maximize future usefulness.

Ice sheet melt suppresses Antarctic snowfall and further accelerates sea-level rise

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Increasing snow accumulation over the Antarctic Ice Sheet (AIS) is a key mechanism for offsetting future sea level rise in a warming climate. In a warmer climate, higher temperatures and reduced sea ice concentrations in the Southern Ocean drive substantial increases in snowfall over the AIS, which could partially counteract increases in ice discharge at the ice-ocean interface. However, most projections of future increases in AIS snow accumulation from Earth System Models neglect feedbacks from meltwater discharge, which have been shown to influence climate. Using the Southern Ocean Freshwater Input from Antarctica (SOFIA) multi-model ensemble, we present preliminary results showing that meltwater consistently reduces Antarctic snow accumulation across models. We compute linear climate response functions to quantify snow accumulation sensitivity to AIS meltwater and show that accounting for the impact of meltwater may increase the AIS contribution to sea level rise by up to a factor of two by 2100 under high emissions scenarios. We present the first multi-model quantification of meltwater-driven reductions in Antarctic snow accumulation and show that ice sheet model projections that do not account for this process may overestimate the role of increased snowfall in mitigating sea-level rise.

Sediment core curation, sampling, and analytical capabilities at Oregon State University Marine and Geology Repository: opportunities for legacy and novel sediment core studies

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Oregon State University's Marine and Geology Repository (OSU-MGR) is responsible for the curation of approximately 50 kilometers of marine sediment cores and >10,000 dredge rocks collected since the 1960's. OSU-MGR hosts four major research collections, including the Antarctic Core Collection, the world's largest collection of seafloor sediment samples from the Southern Ocean, as well as the Marine Geology and Geophysics Collection, a global collection including cores adjacent to other past and present marine terminating ice-sheets and the Arctic Ocean. The global distribution and diversity of the MGR collections, in combination with a suite of modern analytical facilities, offers a unique opportunity to collaborate through research, curation, and education. In addition to long-term storage and archiving services, OSU-MGR includes:

- a main workspace large enough to host major sampling parties, research programs, and educational endeavors,
- an instrumentation laboratory for nondestructive analyses, including five track systems for physical properties, linescan and X-ray imaging, and XRF elemental analyses,
- a wet lab with a fume hood,
- a thirty-person classroom,
- and CT scanning at the College of Veterinary Medicine.

The OSU-MGR collection and analytical facilities are an invaluable resource to support the scientific community's efforts to understand Earth's future. OSU-MGR staff are working to improve metadata records of core inventory using modern digital collection management techniques and improved website functionality. Current and future curation projects comply with FAIR data principles, with the goal of making all OSU-MGR collections and associated datasets more easily discoverable online. We continue to modernize the archival of legacy cores and datasets, including acquisition of updated imagery and nondestructive data, enabling new research on existing sediment cores. We also aim to implement an automated system for assignment of persistent identifiers: IGSNs for cores, rocks, and subsamples collected for requests, and eventually DOIs for data produced in-house. By citing these identifiers in publications, OSU-MGR users will enhance discoverability of samples and data, and therefore the impact of their research for years to come.

Antarctica Ice Mass Loss Since 2002 From Satellite Time Variable Gravity Missions.

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The time variable gravity data from the Gravity Recovery and Climate Experiment (GRACE) and GRACE Follow-On (GRACE-FO) missions document the short term (monthly) and long term (2002-present) changes in ice mass of Antarctica at a spatial resolution of 330 km. The changes in mass combine changes in surface mass balance (SMB) and in ice dynamics. The GRACE results are affected by uncertainties in post glacial rebound, which are low in West Antarctica, but still high in East Antarctica. We use reconstructions of SMB from RACMO2.4p1 to deconvolve the GRACE results. For 2002-2024, the mass loss averages 101±89 Gt/year with a negligible acceleration; the acceleration is only visible in non-GRACE data that extend the record back to the 1970s. A disproportionate amount of the mass loss is controlled by the Amundsen Sea Embayment (ASE) of West Antarctica and to a lesser extent by the Wilkes Land (WL) sector of East Antarctica, which are marine based with a large potential for rapid, multiple meter sea level rise. During 2019-2024, the mass loss paused, which we attribute to an increase in accumulation of snowfall in Queen Maud Land (QML), East Antarctica and the Antarctic Peninsula (APIS). A similar pause occurred in 2002-2007. We examine the loss in five key subregions. The first is the ASE, or basin GH, with the Pine Island, Thwaites, Haynes, Pope, Smith and Kohler glaciers, which lost 124±7 Gt/yr for the entire period due to the enhanced flow of its glaciers. In APIS, or basin I-I", the mass loss averaged 26±5 Gt/yr, decreasing in recent years because of more snowfall. A third sector is Totten, or basin C'-D, with an average mass loss of 23±7 Gt/yr. A fourth is Victoria and George VI Land, or basin D-E, with a mass loss of 2±5 Gt/yr. Fifth, QML, or basins A-B, experienced a positive mass balance of 50±9 Gt/yr. ASE, APIS and C'-D contribute 2,561 Gt, 523 Gt, and 430 Gt of mass loss, respectively, which is partly compensated by a gain of 1,039 Gt in QML. The increase in mass discharge in APIS, ASE and portions of C'D is attributed to intrusions of warm Circumpolar Deep Water (CDW) pushed by stronger westerlies that destabilize the glacier grounding lines. In QML, snowfall increased by +25% starting in 2009 and did not return. The enhanced snowfall may reflect increased storminess in the Indian sector and enhanced evaporation due to a collapsing sea ice cover since 2016.

Near-Total Loss of Buttressing Observed on Pine Island Ice Shelf

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Pine Island Glacier (PIG) drains 10% of the West Antarctic Ice Sheet and has undergone rapid change in the observational record, contributing to uncertainty in sea level rise projections. The Pine Island Ice Shelf (PIIS), which provides a key buttressing force that slows the flux of ice across the grounding line, has accelerated 800 m/yr (an approximate 20% increase in speed) between 2015 and 2024, accompanied by a visible increase in damage in the ice shelf shear margins, indicating a partial loss of buttressing provided by the PIIS. We aim to better constrain the mechanisms through which ice shelves collapse by linking observations of increasing margin damage and ice velocity to modeled loss of ice shelf margin buttressing capacity via increasing damage. We use the Ice-sheet and Sea-level System Model (ISSM) to investigate the instantaneous stress response to imposed margin damage on the idealized glacier and ice shelf domain described in the MISMIP+ experiments. In our model, we are only able to replicate observed changes in stress regime by imposing high damage in both shear margins, greatly diminishing the buttressing provided by the shear margins. This suggests the PIIS is currently providing negligible buttressing to upstream ice, allowing PIG to accelerate, thin, and retreat. We construct a timeline of shear margin evolution and collapse over the PIIS from 2015 to 2024 by comparing modeled stress fields to observed calving events and changes in velocity and strain rate fields. Using this timeline, we conclude the PIIS lost the majority of its buttressing potential after a calving event in 2020, although both shear margins gradually weakened over the course of several years leading up to the calving. We hope to further investigate how the timescales associated with buttressing loss contribute to the style of ice shelf collapse, and determine which ice shelf embayments may be vulnerable to rapid collapse like the collapse of the Larsen B Ice Shelf.

Accelerations of bedrock motions track changing ice mass balance in West Antarctica

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GNSS instruments on bedrock measure the solid Earth deformation response to changing ice mass. GNSS measurement time series across West Antarctica now have robust time series of ~6-18 years in length. New Ohio State velocity solutions for the array of ANET-POLENET sites across West Antarctica reveal changes in bedrock displacement velocities commencing in the ~2020-2022 time period, with coherent timing of acceleration onset in different regions [e.g. Amundsen, Marie Byrd Land, Weddell regions]. Positive accelerations with rate changes up to 10 mm/yr are occurring in coastal West Antarctica. Negative accelerations are occurring in the Weddell region, with displacement slowing by ~1-4 mm/yr. The spatial extent of increasing and slowing uplift [or flips between uplift/subsidence] are coherent with regions of negative and positive ice mass change as derived from GRACE measurements. Elastic displacement time series modeled from EOLIS altimetric measurements of ice height change, converted to mass change, dominantly show good to excellent fits with the GNSS position time series, including timing and magnitude of accelerations. GNSS bedrock displacements in West Antarctica are tracking changing ice mass balance with high temporal resolution.

Geophysical instrumentation in Antarctica: What will be missing and what should be retained?

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Measurements of bedrock displacements by arrays of continuously recording GNSS instruments in Antarctica have transformed our understanding of both spatial patterns and rates of isostatic response of the solid Earth to ice mass change, past and present. Deployment and maintenance of remote instruments is, however, a logistical burden that is increasingly difficult for national Antarctic programs to support, and a near-complete decommissioning of instrumentation in West Antarctica is planned. Guidance from funding agencies included suggestions that ‘only the most compelling science’ can be supported and ‘community consensus’ on priority science and instrumentation locations is needed. As one step toward this, the international community working on glacial isostatic adjustment studies completed a survey in June, 2025. Participants voted on their 3 top choices of ‘compelling science questions’ that can be addressed by GNSS measurements and then ranked regions around Antarctica where GNSS measurements would be most valuable to answer their top questions. All the ‘compelling science questions’ received support, but there was clear consensus on top questions and measurement regions. This presentation will report on the survey results.

SWAIS2C Geophysics: Understanding geologic controls on ice rise formation.

Paul Winberry[1], Huw Horgan[2], Jonny Kingslake[3], Molly Patterson[4], SWAIS2C Science Team
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Sea level rise over the coming century will be dominated by the contribution from Earth's glaciers and ice sheets. The upper bounds of the ice sheet's contribution are poorly known and the principle sources of uncertainty include the West Antarctic Ice Sheet's dynamic response to changing ice shelves. Bathymetric highs can form pinning points that allow ice shelves to exert a constraining force on upstream grounded ice. During the 2025-26 Antarctic field season, as part of the larger SWAIS2C scientific drilling program (https://www.swais2c.aq/), we will perform geophysical investigations on the Crary Ice Rise (CIR), a large pinning point in West Antarctica that resists approximately half the force exerted by the ice flowing from Whillans and Mercer Ice Streams - two of the five main ice streams feeding the Ross Ice Shelf. This presentation will provide an overview of the motivation for continued study of the CIR as well as an overview of planned geophysical experiments. At present planned experiments include surface based active and passive source seismology, phase sensitive radar measurements, as well as borehole seismic and temperature measurements.

Radar Attenuation through the Ross Ice Shelf reveals Melt Shutdown and Accretion of Marine Ice within Basal Channels

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Melt channels have been observed on the underside of ice shelves in both Greenland and Antarctica, and arise when concentrated melt incises a trough into the ice-shelf base. Localized melt within basal channels has drawn considerable attention because of the potential for melt to incise through the shelf and promote fracture. While the mechanisms that promote melt channelization are well studied, the processes that describe how basal channels stabilize, or shutdown, are less well understood. Recently, four basal units were discovered downstream from a system of basal channels that initiate near the Beardmore Glacier grounding zone. Using the Open Polar Radar (OPR) toolbox and radar data collected over multiple seasons, from multiple radar systems reprocessed as part of the OPR initiative, we: calculate depth-averaged and depth-resolved radar attenuation; and, map these basal units from the grounding zone to the calving front of the Ross Ice Shelf. Attenuation as a function of depth increases within these units, which is consistent with the presence of brine inclusions. This suggests that the basal units form due to marine ice that accretes once the melt channels shut down. These observations are supported by layering above the basal units and model experiments that suggest the channels close due to a combination of accretion and creep closure. Since it takes over 100 years for ice to flow from the Beardmore Glacier grounding zone to the calving front of the Ross Ice Shelf, this suggests that melt channelization and accretion has been active for at least the past century. These findings shine new light on the persistence of basal channels in cold cavity ice shelf environments, and demonstrate a new radar reflectivity and attenuation algorithm implemented in the OPR toolbox that can be applied to new and existing OPR data.

The Role of Bedrock Channels in Routing Water Under Thwaites Glacier

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At Thwaites Glacier, radar observations and modeling have suggested that subglacial water transitions into channelized flow downstream. Additionally, observations of the seafloor at Pine Island Bay show bed features in high-resolution, including deep meltwater channels incised into bedrock, which may indicate the flow of subglacial water during past glaciations. Altogether, these observations suggest that stable, channelized flow exists under Thwaites Glacier and has also existed during past glaciations. However, the processes which could drive this transition in subglacial hydrology under Thwaites Glacier are largely unknown.

Here, we explore the role of bedrock channels in directing subglacial water flow. We use a least-cost path routing model to generate subglacial flow paths over idealized bedrock channels in order to assess the relative control of the bed and the surface at varying spatial scales. We modify the bed topography below Thwaites Glacier with bedrock channels similar to those observed offshore in Pine Island Bay, and we examine the influence of these small-scale topographic features on subglacial water paths. Finally, we discuss the potential role of bedrock channels in capturing and concentrating subglacial water.

Turbulence observations beneath the Fimbul Ice Shelf, through a hot-water-drilled borehole

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Antarctic ice shelves are losing mass rapidly, primarily due to oceanic melting, introducing significant uncertainties in future sea-level projections. The melt rate of ice shelves is largely controlled by the turbulent transfer of heat within the ice-ocean boundary layer, a process yet poorly understood due to limited observations. During the 2023-2024 season, we deployed two mooring strings beneath the Fimbul Ice Shelf, positioned above a basal channel, and obtained a year-long time series of key ocean properties. Here we present the estimated turbulent dissipation rate, temperature, salinity and velocity measurements near the ice base, along with the calculated boundary-layer turbulent heat transfer and the ice base ablation rate from an upward-looking sonar. Our calculated turbulent heat transfer agrees with the intermittent melting features of the ice base ablation. Our results will provide new insights into the features of turbulence beneath ice shelves, and how they affect the ice shelf melt rate - critical for improving predictions of ice shelf response to a warming climate.

Interpreting GPS Measurements of Crustal Motion and GRACE Time Varying Gravity in West Antarctica Using GIA Models With 3D Mantle Viscosity

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The glacial isostatic adjustment (GIA) of west Antarctica is a unique case study of mantle viscosity and rheology due to recent ice loss and associated rapid crustal motions both of which are well constrained observationally. In 2018, Barletta et al. used GIA modeling with 1D viscosity to support an extremely weak upper mantle and transition zone below west Antarctica. Such low mantle viscosities (10^18-10^19 Pa s) to a depth of 670 km are inconsistent with viscosities inferred from mantle dynamics at million-year timescales. However, Barletta's 1D viscosity profile may reflect other mantle rheological effects such as stress-dependent or transient viscosity. Here we model the viscoelastic response to recent ice loss in the Amundsen Sea Embayment (ASE) using Maxwell rheology and the finite element code, CitcomSVE 3.0 (Yuan et al., 2025). We constructed a 3D mantle viscosity proxy using global seismic model GLAD-M35 (Cui et al., 2024) and regional model ANT-20 (Lloyd et al., 2020) perturbed around 1D reference viscosity profiles. VM-MZ2021, a reference profile constrained by geoid observations, includes a weak asthenosphere, an upper mantle, and a strong lower mantle (Mao and Zhong, 2021). The surface loading for our trials includes 30 years of elevation change from satellite altimetry data (Nilsson et al., 2022) and an assumed ice history for the century prior to the satellite era. Our GIA model using a 3D mantle viscosity model based on VM-MZ2021 is consistent with GNSS observations within the ASE. In both the basins most impacted by recent ice loss and regions of subsidence, our model reproduces crustal rates observed by five distinct GNSS sites. Between the uplift of Pine Island Glacier and the subsidence of near Thurston Island is a region of subtler crustal motion, where our model is consistent with one site while underpredicting the vertical rates of another GNSS site. Additionally, our results are consistent with the magnitude and pattern of time-varying gravity measured by GRACE. We find that the GRACE observations are dominated by the recent ice mass change, while crustal motion contributes approximately 20% to the GRACE signal. The 3D mantle viscosity structures within our numerical modeling are more consistent with the GNSS observations than their corresponding 1D reference viscosity models motivating us to further pursue 3D viscosity modeling in the ASE region.