AGU Fall Meeting NBP1402 Abstracts

1. East Antarctic land-ice/ocean networks: progress and questions

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Abstract:
International collaborative exploration over the last decade has revealed East Antarctica as a geologically diverse continent underlying an ice sheet with significant sea level potential, parts of which are currently undergoing rapid change. The Wilkes and Aurora Subglacial Basins (WSB and ASB), two of the largest reservoirs of sea level potential in Antarctica, are broader, deeper, and more susceptible to marine ice sheet instability than previously known. The morphology and coastal connections of the ASB indicate a dynamic early ice sheet with a significant erosional history and multiple ice sheet configurations. Recent results imply significant retreat into the WSB during the Pliocene while today irreversible discharge there is halted by only a small ridge.

We have unveiled complex contemporary subglacial landscapes beneath both basins providing new challenges and opportunities to ice sheet modelers. For instance, geothermal heat flow varies spatially on multiple scales in the continental crust assumed to be homogeneous. A large, active, subglacial hydrological system flows through the ASB along pathways that likely predate large-scale glaciation.

Proxies indicate four to eight meters of global sea level rise during the last interglacial period. Ice core results constrain the amount of sea level rise to one to three meters from contributed by East Antarctica. Going forward, new altimetry data along the East Antarctic coast reveal extensive lowering of the Totten and Denman Glaciers while satellite gravity indicate a variable but persistent record of negative regional mass loss. These discoveries provide a new baseline as the international community increases its focus on the region through ongoing airborne and marine exploration to address the many outstanding questions:

What is the character and distribution of subglacial boundary conditions and water systems upstream of the grounding line in areas of significant potential sea level impact?

How much subglacial water discharges into sub-ice shelf cavities and what is its impact on the ocean?

How do ocean forcings drive variations in ice surface elevation change and grounded ice mass budget?

How does ice shelf cavity geometry affect sub-ice shelf circulation, and melt/freeze distribution in areas of significant potential sea level impact?

2. On the Revealing Firsthand Probing of Ocean-Ice Atmosphere Interactions off Sabrina Coast During NBP1402

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Abstract:
Diverse interactions of winds, currents and ice around Antarctica dictate how, where and when the world's densest waters form and massive floating ice shelves and glaciers melt, as well as control sea surface gas exchange and primary productivity. Compelled by recent rate estimates of East Antarctic Ice Sheet mass loss, we contrast the paths and mixing histories of oceanic waters reaching the continental ice edge off the Sabrina and Adelie coasts relying on the unique set of synoptic shipboard measurements from NBP1402 (swath bathymetry, ADCP, underway CTD).

Analysis of historical hydrography and sea ice concentration fields within the Mertz Polynya indicates the apparent effect of evolving ocean-ice-atmosphere interactions on the characteristics of local Shelf Water (SW) sources to current outflow of newly formed Antarctic Bottom Water (AABW). A polynya dominated water mass structure similar to that observed off the Adelie Coast before the removal of the Mertz Ice Tongue was expected to the west of the Dalton Ice Tongue (DIT). However, we found no evidence of dense SW off Sabrina Coast, which may lessen the region's preconceived influence to global meridional overturning.

Present sea ice production within the eastern Dalton Polynya is overshadowed by freshwater input to relatively stable interior upper waters. The Antarctic Coastal Current (ACoC) picks up distinct meltwater contributions along the DIT western flank and in front of the Moscow University Ice Shelf (MUIS) and Totten Glacier (TG). Unlike over other highly influential margins to global sea level rise, there is no evidence of local cross-shelf inflow and mixing of warm Circumpolar Deep Water. Relatively cold thermocline waters from the continental slope enter the eastern trough off Sabrina Coast, and they are swiftly steered poleward by complex underlying topography. Meltwater export from beneath the MUIS and TG is observed at newly discovered trenches that effectively constrain sub-cavity inflow to low salinity near-freezing waters drawn from intermediate levels of the adjacent westward flowing ACoC.

Winds, currents and ice interactions observed off Sabrina Coast during NBP1402 are most likely widespread, in view of reported decadal freshening of upper waters over the Antarctic continental shelf and their localized AABW outflows.

3. High-resolution Deglacial to Holocene paleoceanographic records from the Sabrina Coast, East Antarctica: Preliminary foraminifer-based results from NBP14-02

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Abstract:
Cruise 14-02 of the RV/IB *N.B. Palmer* conducted the first multidisciplinary oceanographic investigation of the continental shelf within the Dalton Iceberg Tongue polynya off the Sabrina Coast, East Antarctica. At >350 m in the northeastern polynya, hydrographic measurements

confirmed that relatively warm (>0°C) oceanic thermocline water from near the shelf break has been imported to the shelf but likely within an interior recirculation associated with local mid-shelf bathymetry. CHIRP sub-bottom data revealed ~15 m of acoustically transparent sediment in a 550-m deep basin proximal to this feature. A suite of coring devices was used to recover a complete 13-m sequence of Late Pleistocene glacial diamict and Holocene laminated diatom oozes and muds (NBP14-02 MC 45, KC 27B, JPC 27, and JKC 53) with chronology constrained by ^{210}Pb and foraminifer-based AMS ^{14}C dates.

Unlike many Antarctic margin sedimentary sequences, biogenic carbonate ($CaCO_3$) is exceptionally well preserved throughout the sedimentary sequence, likely due to non-corrosive bottom waters and/or low sedimentary organic carbon content. Planktic foraminifer *Neogloboquadrina pachyderma*(s) is present throughout and abundant in the diatomaceous muds. *Bulimina aculeata,* which prefers calm, hemipelagic environments and bottom water temperatures >0°C, dominates the living benthic foraminifer assemblage.

Fossil assemblages oscillate between *B. aculeata* and *Trifarina angulosa*-dominated assemblages. As *T. angulosa* is associated with oxygenated bottom waters and strong bottom currents, this assemblage may record past changes in the location of the Polar and Slope Fronts. This interpretation is supported by *T. angulosa* presence in *Thalassiothrix* diatom oozes, which are associated with oceanic frontal zones and rapid biosiliceous sedimentation. Preliminary foraminifer oxygen and carbon isotopes, *N. pachyderma*(s) presence, and the observed *T. angulosa* Mg/Ca-temperature (-1.8 to 0°C) relationship highlight the potential for detailed regional foraminifer-based paleoceanographic records, which will provide critical tests for developing proxies, including TEX_{86} paleothermometry. Future paleoceanographic studies will be supported by data from two long-term oceanographic and sediment trap moorings deployed near the core site.

4. Environmental and ice volume changes based on seismic stratigraphy in Sabrina Coast, East Antarctica: Preliminary results from NBP1402

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Abstract:
In 2014, the R/V *Nathaniel B. Palmer* (NBP1402) sailed to a virtually unexplored continental shelf along the Sabrina Coast, East Antarctica. The shelf contains the sedimentary record of environmental and ice volume changes within the Aurora Subglacial Basin (ASB), which is presently occupied by ~7 m sea level-rise equivalent of ice. We acquired 750 km of high-resolution seismic data proximal to the Reynolds Trough and Moscow University Ice Shelf glacial systems west of the Dalton Ice Tongue using dual 45/45 cu. in. G.I. guns and a 24 ch. streamer with 3.125 m groups providing a vertical resolution of ~3 m simultaneously with CHIRP data. These are the first images of this margin acquired and show a remarkable set of sequence stratigraphic transitions. Crystalline basement is at the seafloor landward and buried seaward with a transition to smoother reflection interface. Reflective sedimentary strata overlie the basement, dip seaward, and are capped by a landward-dipping regional angular unconformity. Above this are a series of transparent seismic facies that, along with the middle to outer shelf seafloor, dip landward towards a shelf-oblique glacial trough. The older, seaward-dipping strata include a

deeper series of units that display at least three stratal architectures interpreted to be shelf deltas implying a pre-glacial, fluvial environment within the drainage basin. Above these sequences, the seismic facies transition to surfaces exhibiting significant erosion, small u-shaped valleys, and channel fill sequences, all of which are reminiscent of temperate glacial features. We interpret these sequences as including sub-ice tunnel valleys and grounding zone wedges with interspersed non-glacial to pro-glacial deposits. Increasing glaciogenic facies upsection suggests a gradual fluvial to glacial transition and increasing glacial extent with time. The subsequent transition to ice sheets is marked by erosion to basement landward and the angular unconformity seaward. The unconformity is overlain by glacial diamict, representing an incomplete record of cold-based glaciations after the ASB became ice-filled. Correlations with cores collected above and below the unconformity and deltaic unit should allow us to determine the ages of these transitions from fluvial to polythermal to ice sheets in East Antarctica.

5. The geomorphic and sedimentary record of past subglacial water outbursts, Sabrina Coast, East Antarctica

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Abstract:
The drainage basin of Totten Glacier (TG) comprises nearly one-eighth of the East Antarctic Ice Sheet and contains an estimated ice volume equivalent to 6.9 m of eustatic sea level rise, a value greater than the entire West Antarctic Ice Sheet. Adjacent, and partially covering the area presently corresponding to TG drainage basin, is the Aurora Subglacial Basin, a deep trough that reaches more than 1 km below sea level where geophysical data suggest the existence of numerous subglacial water bodies. Such water bodies maintain zero basal shear stress relatively to the overlying ice. It is theorized that subglacial outburst would decrease the shear stress at the bottom of marine ice sheets near the margin, inducing ice acceleration, thinning and ultimately contributing to the collapse of the ice sheet. In this contribution we present part of the preliminary results of the first geological and geophysical marine survey (NBP1402) to the inner continental shelf off the Sabrina Coast in the Totten Glacier/Moscow University Ice Shelf area, East Antarctica. We describe a set of subglacial features that we interpret as representing the sedimentary and geomorphic record of past subglacial water outbursts. These features, which we refer as “feather moraines”, were imaged by high-resolution multichannel seismic (MCS) and CHIRP data to consist of a stack of subglacial sediments separated by erosional unconformities, and were shown in the swath bathymetry to consist of feather-like areas exhibiting cross and cut relationships between different sets, with distinct step-wise borders on the downstream side. They are superimposed on megascale glacial lineations (MSGL) and are elongated in generally the same direction as the MSGLs. The upstream side of the feather moraines coincides with the initiation of the MSGL and an area of drumlins near the limit of the glacial sediments and the outcropping of bedrock. A network of channels carved in bedrock just south of the feather moraines point in the direction of these geomorphic features suggesting a genetic link. The MCS imaged architecture indicate a constructional origin with progradational facies on the downstream side, and complex array of unconformable surfaces separating different growth stages. Ongoing sedimentary analyses of core samples taken from these features will be discussed.

6. NBP14-02: The Sabrina Coast Marine Record of Ocean-Cryosphere Dynamics

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Abstract:
In January 2014, an international research team embarked on a multidisciplinary ship-based expedition (NBP14-02) to the Totten Glacier/Moscow University Ice Shelf (TG/MUIS) area on the Sabrina Coast, East Antarctica. This system marks the termination of the largest marine-based portion of the East Antarctic Ice Sheet (EAIS; ~7 m sea level potential), yet little is known about its stability. Recent satellite data indicate regional ice thinning of TG/MUIS, possibly related to ocean-induced basal melt. However, the adjacent continental shelf was not comprehensively surveyed before NBP14-02 due to its remoteness and predominant sea ice cover.

NBP14-02 scientists conducted physical-chemical, geophysical, and geological surveys of this practically unexplored region to evaluate recent and longer-term ocean-cryosphere linkages. Hydrographic measurements revealed southward transport of relatively warm subsurface waters from near the shelf break to the mid-shelf that weakened farther south near the ice shelf edge, contrary to initial hypotheses. Swath bathymetry mapped many glacial features, suggesting a complex regional glacial and deglacial history. We identified a network of channels scoured into bedrock that were spatially associated with glacial geoforms and may have formed during large subglacial meltwater outbursts. Over 750 km of high-resolution multichannel seismic data were acquired. Seismic profiles revealed the region's geologic and climatologic history since the onset of Antarctic-Australian rifting, including evidence for: 1. fluvial deltaic systems, 2. intermittent glaciations, 3. the onset of persistent glaciation and significant ice loading, and 4. more recent glacial advance and retreat cycles. Coring and dredging operations, guided by geophysical data, enabled the collection of older sediments from outcropping unconformities and expanded Holocene sequences from restricted basins.

The multidisciplinary nature of NBP14-02 enabled a rapid, but detailed, baseline assessment of a previously unexplored area. This approach was useful for introducing students to a broad range of oceanographic techniques and ideal for research expeditions subject to the unpredictable nature of the short Antarctic field season.

7. Holocene Sedimentary Record of Unusual Primary Productivity, Dalton Polynya, Sabrina Coast, East Antarctica

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Abstract:
Cruise NBP14-02 surveyed the previously unstudied Moscow University Ice Shelf region, East Antarctica, an area of concern due to recent changes in the glacial system. Using 3.5 kHz sub-bottom geophysical data, we targeted a mid-shelf site with an expanded Holocene sedimentary section, recovering ~ 10 meters of Holocene diatom-rich sediments characterized by an unusual floral assemblage that records the strong and consistent presence of open ocean diatoms. The sedimentary assemblage is dominated by ~50% *Fragilariopsis kerguelensis*, with a diagnostic contribution of *Thalassiosira lentiginosa* and *Thalassiosira oliverana*, species typical of the open Southern Ocean, suggesting southward inflow onto the shelf. A lesser contribution of *Fragilariopsis curta* indicates the influence of sea ice associated productivity within the polynya. Strong easterly winds and the blocking of sea ice transport into the region by the Dalton Iceberg Tongue to the east appear to be important factors in polynya development and maintenance; sea ice melt within the polynya likely contributes a diatom seed population. *Chaetoceros* is notably absent, likely due to the polynya opening later in the season (January) and the absence of a typical spring bloom. Unusual *Thalassiothrix antarctica* layers, up to 15 centimeters thick and comprised of tightly matted valves with a newspaper-like texture, are evident down core. This shade-adapted species can live at depth, maximizing access to nutrients, and is thought to be an under-recognized contributor to oceanic primary productivity due to the patchy subsurface nature of blooms. *Thalassiothrix*, and other species with a similar thread-like morphology, are often associated with oceanic frontal zones and may be responsible for episodic but significant carbon and silica flux to the sea floor. Temporal variability in the occurrence of *Thalassiothrix* layers in this Holocene sediment sequence may reflect past changes in the relative proximity and/or strength of Polar and Slope Fronts and/or changes in onshore current flow and strength, transporting large, cohesive diatom mats onto the shelf. Future down core diatom assemblage studies will improve understanding of regional ocean-cryosphere interactions in an environmentally sensitive region.

8. Pre-glacial, Early Glacial, and Ice Sheet Stratigraphy Cored During NBP1402, Sabrina Coast, East Antarctic Margin

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Abstract:
Western Wilkes Land provides an unusual setting with regard to passive margin subsidence and exposure of Cenozoic sedimentary units across the continental shelf, due to the unique rift to drift history off of the Australian-Antarctic Discordance and subsequent deep glacial erosion of the evolved continental shelf. The first factor has provided extensive accommodation space for the preservation of stratigraphic sequences that in turn represent critical periods in the climate evolution of Antarctica. Glacial erosion has then provided access to this stratigraphy that is usually inaccessible to all but deep drilling programs. Such stratigraphies are well exposed to

within cm of the seafloor off the Sabrina Coast. Cruise NBP1402 investigated this region via a combination of multi-channel seismic imaging and innovative, strategic coring. The geophysical data imaged the geologic evolution of the margin, which exhibits a continuum from non-glacial, partly glaciated, to fully glaciated depo- and erosional systems. Based on the seismic stratigraphy, we collected dredges and one barrel Jumbo Piston Cores (JPCs) across areas of outcropping strata imaged seismically, a unique strategy that allowed us to identify and sample specific reflectors. The stratigraphically deepest coring targeted sections for which the seismic character suggested a pre-glacial context, with non-glaciated continental margin sequences including deltas. Coring recovered dark organic rich siltstones and sandy mudstones, and a large concretion whose center contained a cm-sized plant fossil. In addition, the sediments contain a fossil snail. These fossils provide a glimpse into the pre-glacial terrestrial environment in Antarctica. Overlying this section, coring recovered similar dark siltstones with a 20 cm thick horizon with abundant large angular clasts of variable lithology, interpreted to be ice-rafted debris and indicative of early glacial ice in Antarctica. Finally, JPCs targeting a younger part of the sequence recovered diatomites suitable for biostratigraphic control. We highlight this new mode of operation for JPCs as a relatively inexpensive way to acquire stratigraphic samples at key seafloor outcroppings with the tremendous benefit of being able to conduct this kind of sampling from a mobile platform in icy waters.

9. Seismic Stratigraphy of Ice Sheet Advance-Retreat Cycles on the Sabrina Coast Continental Shelf, East Antarctica

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Abstract:
2D multichannel seismic (MCS), multibeam and CHIRP data were collected as part of the recent *R/V Nathaniel B. Palmer* (NBP1402) cruise to investigate the marine record of cryosphere-ocean dynamics on the continental shelf between the Dalton Ice Tongue and Totten Glacier systems. Outlet glaciers and ice shelves along this coastline drain a catchment area extending across the Aurora Subglacial Basin (ASB) whose topography lies below sea level and contains an ice volume of approximately 6.9m of sea level rise equivalent. Analysis of over 750km of high-resolution MCS data has revealed the preservation of extensive tilted fluvial-deltaic shelf sedimentation and the first evidence of polythermal glacial advance in this region with well-preserved subglacial meltwater channels and tunnel valley systems. This expansive fluvial to glacial sedimentary section is separated by a regional unconformity from a series of irregular, localized unconformities preserved in an otherwise seismically transparent facies. We interpret these transparent facies as subglacial diamictites deposited over several glacial cycles. Detailed seismic stratigraphic analysis of the glacial sequences above the regional unconformity identified at least 4 glacial cycles illustrated by grounding zone wedge moraine deposits recorded in both MCS and multibeam bathymetric data. Distinct differences were evident in the stratigraphic architecture of polar versus polythermal glaciations including greater preservation of till deposits above the regional unconformity proximal to the exposed bedrock boundary and the present-day ice front. Sedimentary sequence preservation here appears dictated by the geometry of local ice

advance and allied basement structure controls. Integration of marine geology, high resolution CHIRP and multibeam bathymetry data with MCS sequence geometry and acoustic facies mapping has led to improved constraints on rates, styles and patterns of glacial retreat. Such improvements to deformable sediment distribution and lithologic character constraints are critical to numerical ice sheet model flow velocities and potential instability assessments, and continue to advance our understanding of ice sheet dynamics and basal conditions across both heavily fjorded and uniform basement architectures.

10. Increasing Ocean Access to Totten Glacier, East Antarctica

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Abstract:
The Totten Glacier Ice Shelf (TGIS) is the primary outlet of the Aurora Subglacial Basin, draining 6.9 meters of eustatic sea level potential into the Sabrina Coast (SC) alongside the Moscow University Ice Shelf that fringes the coastline. The TGIS and surrounding grounded ice has the largest thinning signal in East Antarctica and the nature of the thinning suggests that it is driven by enhanced basal melting due to ocean processes. Warm Modified Circumpolar Deep Water (MCDW), which has been linked to glacier retreat in West Antarctica, has been observed in summer and winter on the SC continental shelf in the 400-500 m depth range. Here we show, using new data from recent aerogeophysical flights, that entrances to the cavity exist that are deeper than this range of thermocline depths, indicating that the TGIS is vulnerable to intrusions of MCDW if the vertical structure of cavity inflow is similar to the nearest observations. We provide evidence that a new entry to the cavity has opened likely due to the interplay between thinning ice and subglacial channels that could be related to regional mass loss acceleration observed in 2006. This new connection may increase access of warm water to the east side of the ice shelf, potentially destabilizing the low-lying area to the east of the TGIS.