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SESSION 8

PAST TO FUTURE INTERPLAY BETWEEN ICE SHEETS IN THE WORLD AND REGIONAL TO GLOBAL TELECONNECTIONS

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Australian-Antarctic rift-drift transition and development of the Antarctic Circumpolar Current – new IODP drilling in the Australian-Antarctic abyssal plain

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Despite many efforts, fundamental questions remain about the timing of onset, steps in development and attainment of present-day vigour of the Antarctic Circumpolar Current (ACC). Tectonic Australian-Antarctic (AA) separation played a critical role in this development, but the true nature of this tectonic opening remains elusive: timing of and mechanisms during the rift-drift transition, as well as post-rift subsidence history, are poorly constrained by the available sedimentary archives. The development of the ACC during subsequent seafloor spreading is poorly documented. We here present a pre-proposal for IODP to drill and collect the unique rock archive recording the onset and nature of ocean crust formation, and sedimentary archives across the core of the flow path of the ACC, where it is unobstructed by geographical boundaries. Through this, our drilling proposal innovatively connects structural geologic/geophysical objectives with paleoclimate/paleoceanographic objectives. We also present expedition plans to survey the AA abyssal plain sedimentation processes under influence of both ACC and Antarctic bottom water flow. In our drilling plans, one site from the Australian continental rise/abyssal plain transition will recover peridotite ridge/basement rocks and portray the overlying sedimentary conditions reflecting post-rift subsidence. A site on the Antarctic continental rise will reveal the subsidence history conjugate to the Australian margin. Two sites on the AA abyssal plain will represent the Cenozoic evolution of the ACC flow. All four sites combined will complete the latitudinal transect of sediments necessary to reconstruct the evolution of latitudinal sea surface temperature gradients, a keystone feature of the present-day vigorous ACC.

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Oceanographic and temperature consequences of tectonic opening of the Tasmanian Gateway

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Over the course of the Cenozoic (66-0 Ma), tectonic rift between Australia and Antarctica opened and progressively widened the Tasmanian Gateway. The regional oceanographic consequences and therefore the role of Tasmanian Gateway changes in the onset of Eocene cooling, Antarctic glaciation and proliferation of sea ice, and the development of a modern-day-like Southern Ocean oceanography are poorly resolved. Through various research projects over the past years, we have generated quantitative temperature reconstructions (sea surface and land temperature, based on fossil lipid biomarkers), from biomarker data, combined with dinoflagellate cyst assemblages, to reconstruct the paleoceanographic conditions around the Tasmanian Gateway. We generated data from ODP Site 1172 in the Southwest Pacific Ocean (Maastrichtian- Oligocene), ODP Site 1170 (South Tasman Rise; Middle and Late Eocene), ODP Site 1168 (west Tasman margin; late Eocene-recent), The Otway Basin (southern Australia; late Paleocene - early Eocene), DSDP Site 274 (offshore Cape Adare; Oligocene-early Miocene) and IODP Site U1356 (Wilkes Land Margin; Eocene-Miocene). We recognize the surprisingly similar temperature conditions on either side of the Tasmanian Gateway prior to opening (ca. 50 Ma), during the Paleocene and Eocene, a progressive cooling on both sides as the gateway first opens during the early Eocene and still warm ice-proximal conditions during the Oligocene and Miocene. A progressive development of the SST gradients and modern-like frontal systems is found from the late Miocene onwards. Collectively, our records provide a comprehensive overview of the oceanographic and climatological consequences of the opening of the Tasmanian Gateway.

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Comparison of high-latitude interannual variability of the Northern and Southern Hemispheres during the last glacial-interglacial transition.

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A preliminary high-resolution water isotope record has recently been recovered from the East Greenland Ice Core Project (EGRIP). This record is currently dated to 15 ka but additional work will allow a depth age scale through about DO event 12 (50+ ka). There also exists a 5 cm resolution NGRIP (North Greenland Ice Core Project) water isotope record for high resolution comparison. Using these records, we will determine how interannual and decadal variability changed across the last glacial-interglacial transition. Previous research from the WAIS (West Antarctic Ice Sheet) ice core revealed a 50% reduction in the amplitude of interannual variability after 16 ka, due to climate dynamics of the tropical Pacific and ultimately the topography of the Laurentide ice sheet. This finding was remarkable in that the large northern ice sheets greatly affected southern hemisphere climate. Did a similar shift in high frequency climate variability also occur in Greenland, which was much closer to the Laurentide ice sheet? We'll explore this possibility using the EGRIP and NGRIP records, and make comparisons with a new record from South Pole (east Antarctica) and the existing WAIS record. We hypothesize that a different signal will be present at these Greenlandic sites because north Atlantic climate variability is driven by substantially different climate dynamics than those in the Pacific. Ultimately, we will test our results using global circulation models and present the most up to date results at this conference.

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Inter-annual variability of Antarctic Sea Ice Extent and Indian Summer Monsoon Rainfall

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Teleconnection between the variability of the Antarctic Sea Ice Extent (AnSIE) and the tropical climate has been extensively investigated. The study examines the interannual relationship between the variability of sea ice extent in the Indian Ocean (SIEIO) sector (20º–90ºE) and Indian summer monsoon rainfall (ISMR) under the influence of the Mascarene High (MH). SIEIO in high (HIP) and low (LIP) ice phase years during April-May-June (AMJ) appeared to have a significant correlation to ISMR in the Peninsula India region during June-July-August-September (JJAS), with correlation coefficients of 0.51 and 0.71, respectively. Composites of mean sea level pressure (MSLP), 500 hPa geopotential height, and 850 hPa wind anomalies during HIP and LIP also showed that there was a relationship between the SIEIO and the MH, revealing that HIP and LIP correspond respectively to the strengthening and weakening of the MH as well as increases/decreases in ISMR. During the respective HIP and LIP years, positive and negative MSLP anomalies were found respectively, particularly over the MH region associated with the eastwards and westwards shifts of its center from the normal locations. Similar features were also observed at 500 hPa geopotential height anomalies. In addition, 850 hPa wind flow illustrated strong anti-cyclonic and cyclonic anomalies in the MH region, which lead to corresponding strong and weak southwesterlies and thus respective positive and negative ISMR anomalies. Hence, a positive MH anomaly was associated with more ISMR

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Can we improve the reconstructions of Antarctic snow accumulation over the last centuries by using climate information from outside Antarctica?

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Reconstructing the Antarctic climate over the last centuries is challenging because the number of records (mostly composed of ice core records) is low and they are unevenly distributed over the continent. However, numerous studies have shown strong teleconnections between the Antarctic climate and the climate at higher latitudes of the Southern Hemisphere. Those regions offer a larger and a more varied climate proxy network than Antarctica, in particular tree ring widths. Here, we aim to constrain the drivers of Antarctic snow accumulation at the regional scale over the last centuries by providing a new snow accumulation reconstruction that incorporates information from the Antarctic continent and from higher latitudes in the Southern Hemisphere. The relationships between the regional Antarctic snow accumulation and a wide range of climate variables over the Southern Hemisphere are first assessed in reanalysis data and climate models to identify the regions and data that are the most likely to improve reconstruction skill. Specifically, we will assess here the locations north of the Antarctic continent where relevant proxy data is found for Antarctic snow accumulation reconstruction. This will also be the opportunity to evaluate the ability of climate models to simulate observed teleconnections. Based on these results, we reconstruct the snow accumulation as well as the surface air temperature, atmospheric circulation and sea ice cover over the last centuries. This is achieved by data assimilation that is able to combine different types of records, taking advantage of their covariance as represented in climate models.

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Antarctica and Greenland ice sheet mass loss from multiple-satellite data, and impact on global and regional sea levels

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Understanding the long-term changes in the ice sheets of Greenland and Antarctica has global climate significance, especially on long term global and regional sea level rise predictions. We present results of current satellite-derived ice sheet change time series of Greenland and Antarctica, using satellites such as GRACE, GRACE-FO, CryoSat and IceSat, covering up to a 28 year time span, building in part on data available through the ESA Climate Change Initiative. The space data highlight the dynamic nature of the ice sheet changes, including the large interannual variation and regional accelerations of ice mass loss regions, which make short term predictions of ice sheet melt challenging due to decadal-scale regional climate changes. The accelerations of the ice sheet melt have direct impact on the sea level rise, with “fingerprinting” of these effects due to earth rheology and gravitational changes showing big changes in the vulnerability of different coastal regions to future sea level rise.

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A new conceptual model for interpolar climate coupling during the Ice Ages

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The thermal bipolar seesaw model by Stocker and Johnsen is widely used to explain the connection between abrupt Dansgaard-Oeschger events in Greenland and their climate response in Antarctica. We now have better-dated records from Greenland and Antarctica with higher resolutions which provide critical information into furthering our understanding of interpolar climate coupling. Records of water isotopic composition from Greenland and Antarctic ice cores were used as a proxy for past temperatures. MatLab was the primary tool used for data analysis, combining statistical correlation and modeling on the updated data sets. The data were first used to replicate the bipolar seesaw. WAIS Divide, Talos Dome, and EPICA Dome C produced the best depiction of the seesaw, whereas EPICA Dronning Maud Land and Dome Fuji had much lower correlations even though their proximity is closer to the South Atlantic. Next, we suggest a simple conceptual model that can replicate both millennial and orbital-scale Antarctic climate during the last ice age using greenhouse gas forcing, surface albedo, and the AMOC. Modeling results suggest Antarctic climate simply reflects the mean ocean temperature; in this view it is the global ocean interior, rather than the Southern ocean, acting as the heat reservoir in the bipolar seesaw. By using three AMOC states (strong, weak, and off), we can simulate the D/O cycle and glacial terminations, confirming the seesaw is a necessary part of the machinery of glacial cycles. The success of our simple model approach suggests a revised view of the seesaw concept may be warranted.

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Spatio-temporal terrestrial sediment input in the Bellingshausen and Scotia Seas and its implication for sedimentation mechanism since the last glacial period

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Magnetic susceptibility (MS) record of sediment cores from the Scotia Sea showed a strong correlation with ice core dust record, consequently the graphical correlation between them can be used for age model establishment. However, the exact mechanism is still controversial. In addition, this correlation is mostly found in the Scotia Sea, which limits our understanding. We found that the MS variation of a sediment core obtained in the Bellingshausen Sea continental rise shows a co-variation with ice core dust record. We document MS, CaCO3 concentration, and ITRAX scanned elemental ratios (Ca/Ti and Ti/Rb) of cores from the Bellingshausen Sea and the Scotia Sea to compare the temporal variation of terrestrial sediment input and its source region in the two regions. Ca/Ti is often used for biogenic carbonate/detrital ratio, but no relationship between CaCO3 concentration and Ca/Ti ratio, indicating that Ca/Ti ratio here can be used as a provenance proxy together with Ti/Rb. Although the variations of MS and Ca/Ti ratios co-vary (high during glacial periods), Ca/Ti and Ti/Rb ratios showed a longitudinal difference. This suggests that the MS variation from the Bellingshausen Sea to the Scotia Sea, even within the Scotia Sea, is not controlled by dust input and oceanic current which were previously proposed as the main mechanism. However, if it is controlled by ice shelf calving activity during glacial periods as recently proposed, the regional co-variation with different provenances can be explained well. Our study shows the glacial dynamics in the West Antarctica were synchronous.

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Paleoclimate change with diatom assemblage in the Ross sea coastal core sediment

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Study the climate change recorded in the core deposits at the Antarctic coast, the geochemistry data and the diatom assemblage in the piston core deposits (RS14-GC04) in the Ross Sea. The research area, the Antarctic Ross Sea, is a climate-sensitive area that is believed to have been affected by large and small climate changes during Holocene, which is recorded in the sedimentary layers of the seafloor. The variation of sediment core including diatoms were analyzed from the drilled core which was obtained from the Ross Sea for the purpose of reconstruction of the environmental variations during the Holocene. A total of 12 species and varieties belonging to 29 genera was identified from the core RS14-GC04. The diatom valves per gram of dry sediment range from 3.81×108/g~4.23×109/g in the core. Geochemistry data shows total nitrogen(TN) 0.014~0.233%, total carbon(TC) 0.234~1.508%, total organic carbon(TOC) 0.23~0.151%, biogenic opal(Bsi) 2.90~57.58%, magnetic susceptibility(MS) 0~545 SI 10-5. The results were divided into four facies. Appears in the grounding zone proximal to the open sea environment is seen in the lamination core sediment. When viewed as a position of the core, it appears well after the LGM climate records from the coast. Diatom and other microfossils are often used to restore past climate and environment in land and sea environments, and they are very important indicators of climate change in Antarctic environments. Through the analysis of the diatom assemblage, we want to learn more about the changes in the marine environment in the Ross Sea coast of Antarctica.

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Interhemispheric coupling of abrupt climate change: beyond the bipolar seesaw

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The thermal bipolar ocean seesaw hypothesis was advanced by Stocker and Johnsen, Paleo. [2003] as the simplest possible thermodynamic model to explain the relationship between Dansgaard-Oeschger (DO) and Antarctic Isotope Maxima (AIM) events. Their model invokes a Southern Ocean thermal reservoir, with its heat content modulated by changes in cross-equatorial heat transport by the Atlantic Ocean. Here, we test the seesaw hypothesis using palaeoclimate data and results from a 1-degree GCM that exhibits self-sustained DO oscillations [Vettoretti and Peltier, J. Clim., 2018].

We present four main results. (1) Changes in Atlantic heat transport during the DO oscillations are largely compensated by opposing changes in heat transport by the global atmosphere and Pacific Ocean. (2) Contrary to Stocker and Johnsen [2003], the Southern Ocean is not a major heat reservoir during DO-AIM coupling. This is because the Antarctic Circumpolar Current (ACC) strongly inhibits meridional ocean heat transport. (3) Antarctic warming during AIM events results from increasing poleward atmospheric sensible heat and moisture transport, following sea ice retreat in the Southern Ocean. (4) The Antarctic sea ice retreat is initiated by eddy-heat fluxes across the ACC (principally in the Pacific sector) and amplified by ice-albedo feedback. These results substantiate and expand on earlier work based on a 3-degree GCM [Pedro et al., Quat. Sci. Rev., 2018]. We conclude that the bipolar seesaw is useful heuristic model, but that it misses key processes in the interhemispheric coupling of abrupt climate change.

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Tropical Pacific and Indian teleconnections to Antarctica

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A multidecadal strengthening of the Amundsen Sea Low largely explains the increase in Antarctic sea ice concentration in the eastern Ross Sea and decrease in the Bellingshausen Sea since 1979. Following the long-term overall increase, Antarctic sea ice declined drastically during austral spring 2016, with influences proposed from the 2015/2016 extreme El Niño and a tropical Indian Ocean teleconnection. Here, we examine tropical Pacific and Indian teleconnections to Antarctic sea ice and the adjacent ice sheets using a suite of 'pacemaker' experiments.

The multidecadal strengthening of the Amundsen Sea Low is not captured by freely running coupled climate models, but can be reproduced in simulations of two independent coupled climate models: one constrained by observed tropical Pacific sea surface temperature anomalies and the other by observed tropical wind stress. This analysis further supports the phase change in the Interdecadal Pacific Oscillation from positive to negative over 1979–2013 as contributing to the observed strengthening of the Amundsen Sea Low.

We also conduct experiments using a full coupled climate model forced with observed tropical sea surface temperature to examine the impact of the Indian and Pacific Oceans on southern high latitudes during austral spring 2016. Our experiments suggest a Rossby wave teleconnection from the tropical Indian Ocean contributed to the sea ice decline during spring 2016, with less influence from the Pacific.

These results highlight the importance of accounting for teleconnections from low to high latitudes in both model simulations and observations of Antarctic variability and change.

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Glacier retreat and ocean-atmosphere interactions at King George Island – Antarctic Peninsula

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Glacier retreat is a fact, even in The Antarctic at King George Island (KGI). This study targets to determine glacier retreat and its relationship with climate variability. Multi-temporal analysis with satellite images (Landsat) from 1989 to 2019 and climatic assessment was made. We assess all glaciers located at Admiralty Bay and King George Bay; and additionally, an analysis over only Anna Glacier all of them at KGI. Notwithstanding; all studied glaciers are located at the same place, the glacier retreat rate is different. First, glaciers in direct contact with sea have lost more glacier coverage than the glaciers on continent zone. Second, there was at least equal glacier retreat for period 2005-2007 (only 2 years) and 2007-2014 (7 years).

The first insight over climatology and glacier retreat shows a negative correlation between SST at 3.4 zone - Pacific Ocean and SST around KGI. Consequently, each year evaluation of glacier retreats from 2014-2017 at KGI indicates that whilst the ENSO event (El Niño 2015-2016) occurred, less glacier coverage was lost regarding the normal remaining years (2014 and 2017). Nonetheless, the great glacier coverage loss of 2005-2007 cannot be explained in the same way because for this period, it had only developed a weak La Niña event at 3.4 zone (for such that glacier loss, it might be expected a strong La Niña event). Hence, it is important to understand the key role of ENSO events, SAM, SST, Calvin effect and/or a combination of various of them over glacier retreat at KGI.

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Teleconnections between Antarctic sea ice during autumn and the Indian summer monsoon

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The polar sea ice variability is crucial evidence for climate change. The sea ice variability has far-reaching consequences by affecting the global climate through teleconnections. The sea ice variability in both the hemisphere shows an opposite trend with Arctic sea ice diminishing and Antarctic sea ice increasing till the past few years. The present study examines how the Antarctic sea ice variability during March-May affects the interannual variability of the Indian summer monsoon. The interannual variability of the Indian summer monsoon is punctuated by drought, flood and normal monsoon years. The analysis for this study was done using observational, satellite, and global reanalysis datasets (the NCEP/NCAR and ECMWF Interim Re-Analysis). Preliminary results indicate that the drought years of the Indian summer monsoon are preceded by surface and tropospheric warming over the Indian Ocean sector of Antarctica and cooling over the Ross Sea Sector of the Western Antarctic, during March-May period and the opposite in the case of flood years. The impact of warming is reflected in the sea ice variability also. An important feature observed during the period from 1951 to 2014, is that the years prior and after 2000 differ in the intensity of warming. More analysis and Climate model simulations are required to fully understand the physical mechanism and teleconnections, through which the Antarctic warming(cooling) over the Indian Ocean sector (West Antarctica) sector influences the Indian summer monsoon.

Keywords: Antarctic sea ice, Monsoon, teleconnections

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Glacial-interglacial ACC dynamics in the Pleistocene: Biomarker and dinocyst-based reconstruction of paleoceanographic changes in the Southern Pacific Ocean

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The Antarctic Circumpolar Current (ACC) plays a crucial role in the redistribution of nutrients, upwelling of CO2-rich sub-surface water masses, and delivery of heat to the marine-terminating Antarctic ice sheet, strongly influencing melting rates and sea level rise, eventually. Yet, projections of its future behavior are hindered by the complexity of ACC-associated frontal system migration.
Here, we revisit Pleistocene sediments drilled during Ocean Drilling Program (ODP) Leg 189 around Tasmania. This region represents one of the sectors of the Southern Ocean where the frontal systems of the ACC reach their southernmost position, making it particularly vulnerable to ocean-induced Antarctic ice sheet melt.
We expand on previous work by Nürnberg et al. (2004) by applying organic geochemical as well as quantitative dinocyst assemblage-based proxies on Sites 1171 and 1172 in the Subantarctic Zone and north of the Subtropical Front, respectively, in order to reconstruct Pleistocene sea surface conditions, and thus draw conclusions about past ACC behavior. Our quantitative proxies record past oceanographic conditions, but their response to Southern Ocean frontal system migration has yet been sparsely documented. Additionally, new stable and radiogenic isotope data further improve the records' age models.
Special focus is given to MIS 11 and 5, representing very distinct interglacials and potential analogues for the near future climate under anthropogenic forcing. Preliminary results show strong changes between glacial-interglacial cycles, suggesting strong frontal system migration in this region. This has potential implications for the ocean-induced melting of the Wilkes Land ice sheet as anticipated for the future.

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Atmospheric re-organization during the late MIS3 period driven by local orbital forcing?

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Marine Isotope Stage 3 in Antarctica and Greenland has been a subject of many detailed studies for its characteristic millennial-scale warming events which evoked global impacts. These events, although generally described as oceanic teleconnections and controlled by changes in the North Atlantic climate, are also accompanied by quick and large-scale atmospheric re-arrangements in the form of changes in the latitudinal position of Intertropical Convergence Zone and Southern Hemisphere westerlies. Consequences of such re-arrangements include variability in the strength of the Asian monsoon/tropical precipitation, and changes in the rate of Southern Ocean upwelling, with the latter exerting a key control on atmospheric carbon dioxide concentration.

Here we present a new and high-resolution record of non-sea salt calcium, a proxy for continental dust/latitudinal position of Southern Hemisphere westerlies, from Roosevelt Island Climate Evolution ice core, a coastal record from West Antarctica, and a suite of other proxies, and examine the atmospheric re-organizations that occurred between 26-40 ka BP. We identify an increase in the mean concentration of continental dust in Antarctic ice cores after ~32ka BP, concomitant to the stadial conditions in Greenland, and henceforth we suggest this to be a result of equator-ward displacement of the Southern Hemisphere westerlies. The major implications of such a reorganization include the intensification of Asian monsoon/tropical rainfall and reduction in atmospheric carbon dioxide. Since this time period coincides with Southern Hemisphere summer insolation minima, we propose that a cooling of the Southern Ocean and subsequent sea ice expansion may have triggered this global-scale atmospheric re-arrangement.

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