Slide 1

Hello. I'm Deirdre Ryan, currently a postdoc in the Sea Level & Coastal Changes group led by Dr. Alessio Rovere, at MARUM, University of Bremen in Germany. I would like to begin by thanking Ronadh Cox and Robert Weiss for their invitation to speak to you all. When thinking about what the subject of my talk should be, I thought about how my research, studying ancient coastlines, fits within the session title, "our coastal futures". Ancient, or paleo coasts are incredibly important in helping us predict and prepare for future sea-level change and extreme events. So I thought for this talk, I'd detail some the fieldwork I participated in in 2019 that will produce data useful for the modelling community.

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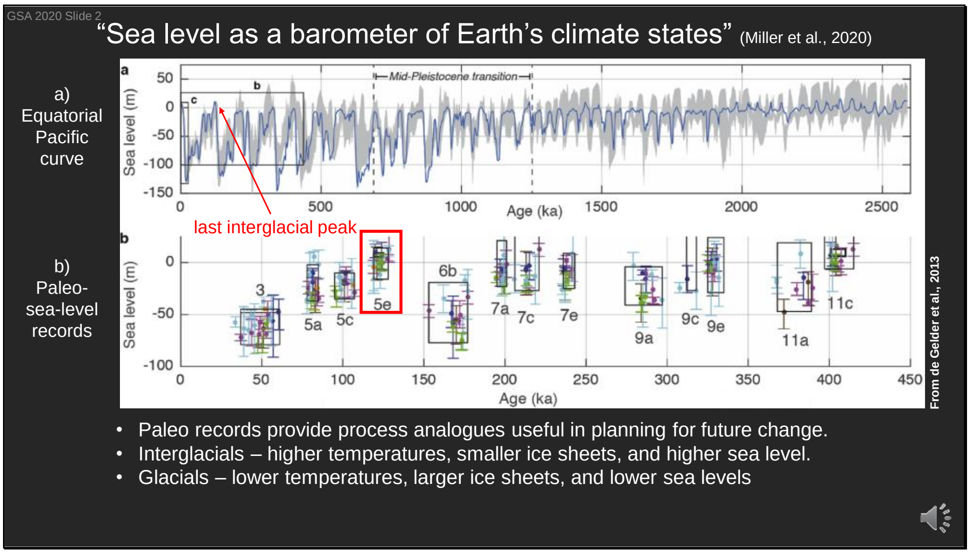

Before we begin the tour, I want to provide a very brief overview as to why paleo studies are so important to our coastal futures and helping us predict what hazards and disasters we might expect in our future. And this phrase here, illustrates extremely well how global sea level is inherently linked to climate through the influence of climate on ice sheet extent and thickness and therefore global sea level.

If you look at a marine oxygen isotope curve the peaks or interglacials correlate with warmer temperatures, smaller ice sheets, and higher sea levels, troughs are glacial periods with cooler temperatures, larger ice sheets, and lowered sea levels, with transition periods in between. Paleo records of sea level help us to understand the interaction between climate, ice sheets, and global mean sea levels.

The last interglacial peak, is our best process analogue for globally higher sea levels and temperatures. During this period, roughly 125,000 years ago, sea levels were somewhere between 2 and 10 m higher than present and the global mean temperature was at least 1 degree C higher. Luckily this record, being so geologically recent, and largely above the height of Holocene sea level and erosion, is fairly well preserved and it is a research priority.

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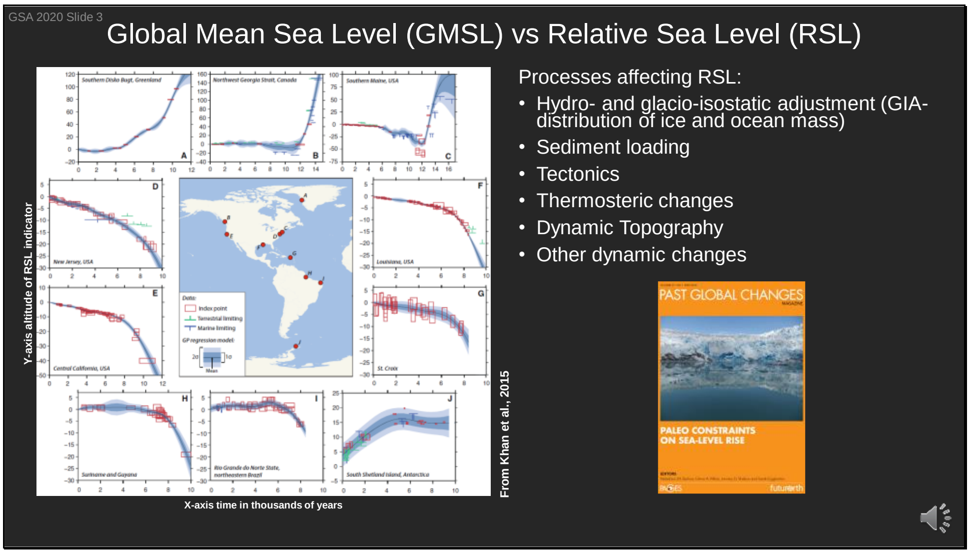

Of course nothing in the real world is as easy as correlating with a point on a graph. Sea-level records are not uniform globally, but regionally specific so that even within the Holocene, as in this example, reconstructions of relative sea level show high variability.

The variability in the record is produced by a number of regional and global-scale processes, which I don't have time to go into, but I recommend this source as a recent approachable summary. However, I will say that one of the largest drivers of variability is glacio-isostatic adjustment, or GIA, which is directly related to the proximity of a location to polar ice sheets; therefore sea-level indicators are used as 'fingerprints' of former ice sheet extent.

The processes influence not only the observed height of sea level and timing of any change, but also the preservation and expression of the physical record. So as you go back further in time they continue to influence the record - thus making it necessary for regional paleo sea-level curves reflecting regional processes in order to model for ice sheet behavior and any future conditions.

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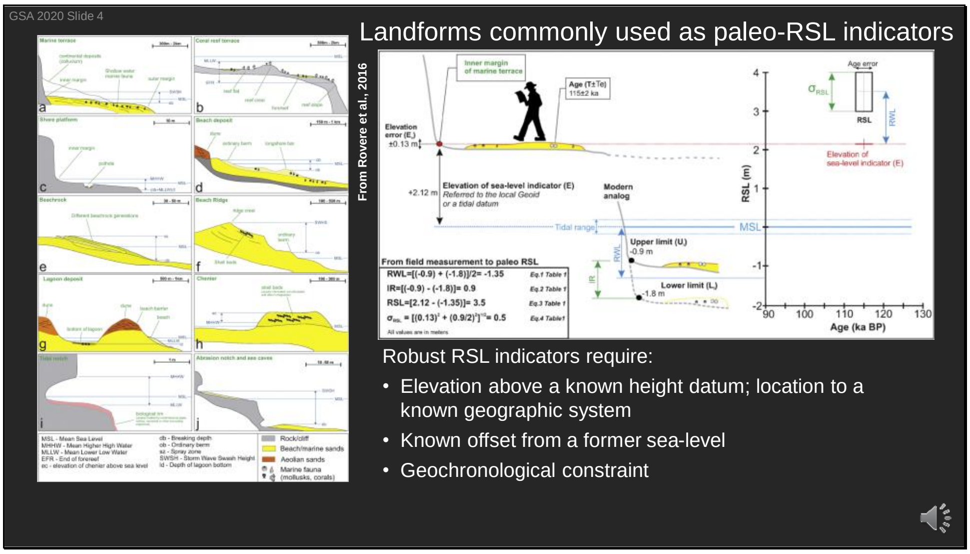

Just quickly, there are a lot of different types of landforms that can be used as indicators. Modern analogues are used by field scientists to constrain estimates of paleo-sea level by providing the upper and lower limits of their formation under modern conditions. The elevation difference between equivalent paleo and modern landform features is the measured relative sea level change. Using standardized methods to measure and define sea level indicators allows for more robust records and better comparison among records.

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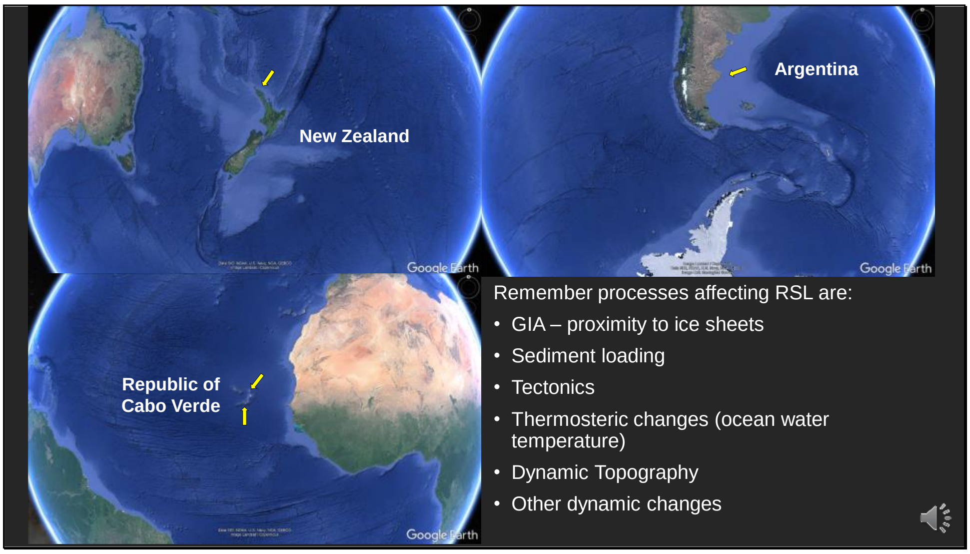

Ok. I am going to take you to 3 locations today that I visited in 2019, the North Island of New Zealand, Argentina, and two islands of Republic of Cabo Verde in the eastern Atlantic Ocean. Most of my fieldwork within my current position has been with the aim to better constrain the last interglacial sea-level record. The southern hemisphere is of particular interest for developing sea-level curves and trying to discern the response of the Antarctic Ice Sheets to climatic change. However, only a very few coastal regions have been subject to the rigorous study necessary to produce the type of robust relative sea level curves needed by modelers. In some instances, it is just because the necessary methods were not available at the time of earlier studies.

Each location, because of the different landscape characteristics and processes, require different approaches in the field. So for each location, I'll outline what tools were used, some initial results where available, and what other research questions were addressed, if any.

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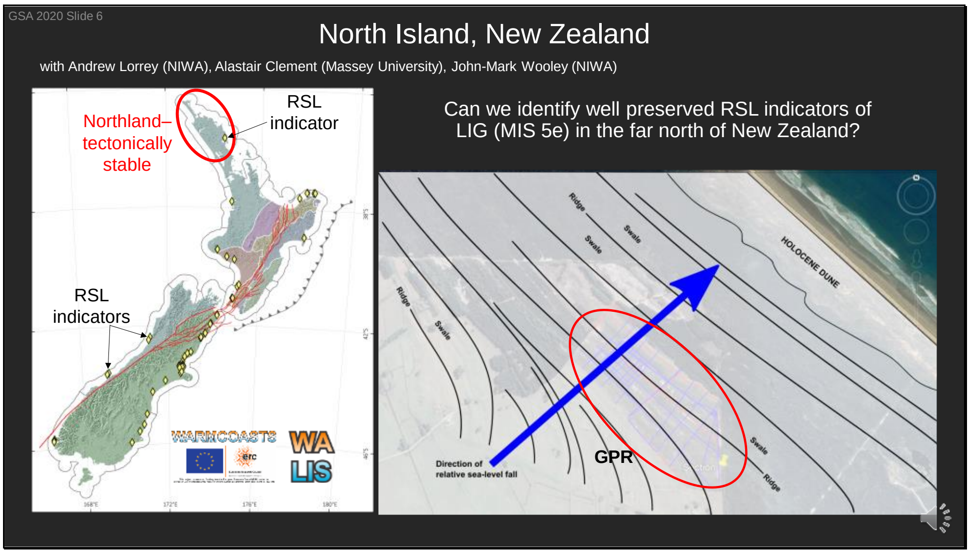

As part of the WARMCOASTS project, which funds my position, I have been working on the development of WALIS, the World Atlas of Last Interglacial Shorelines, which is a database created for the collation of existing and new data on LIG sea-level indicators reviewed following a standardized template. I have reviewed and standardized the LIG sea level record of NZ. That work is detailed in a manuscript submitted to a WALIS special issue within the Earth System Science Data Journal.

Although the Northland region of NZ has been historically considered stable – making it a preferable region from which to develop a regional sea-level curve, only one well-constrained sea-level indicator has been described there.

Last year, with an invitation from Drew Lorrey at NIWA, I went looking to see if additional indicators could be identified.

The Google Earth image shows a prograding beach deposit with ridge and swale topography reflecting a relative fall in sea level. The highest sea level is correlated with the ridges to the west (or left-hand) side of the photo and new ridges formed to the east as sea level fell relative to the land surface.

The lines are where we took Ground Penetrating Radar profiles across a cleared field and on the eastern side of the field we found a quality sea-level indicator.

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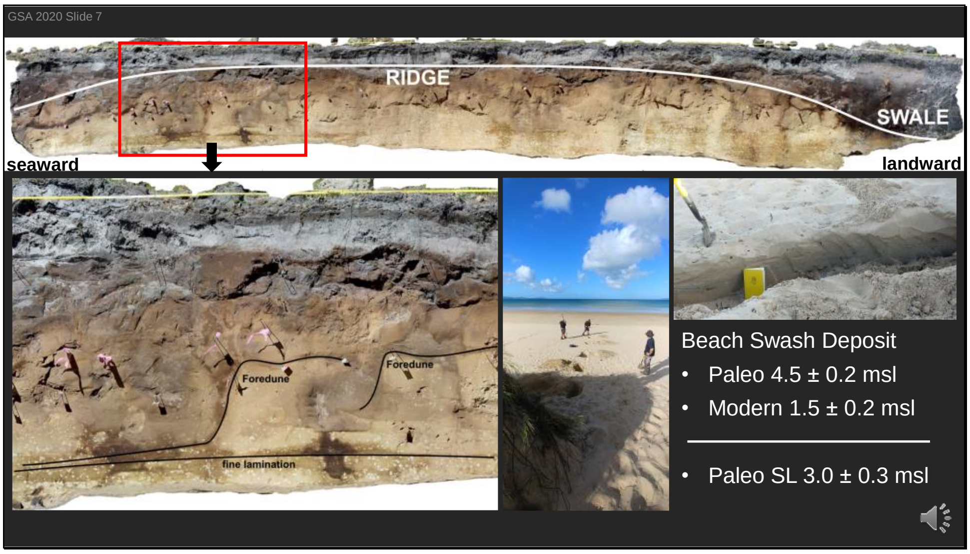

The top image is a transect across a swale-ridge-swale section of the prograding sandy beach sequence in which foredune and beach swash deposits are visible. We cleaned the section and measured elevations with high-resolution dGPS and then went to the nearby beach to collect modern analogues. Initial calculations indicate that at the time of deposition, sea level was approximately 3 m higher than present.

We did collect luminescence samples to determine age, but given context in the landscape and some beyond background radiocarbon results from wood in the overlying peat, we're fairly confident that this is at least within stage 5.

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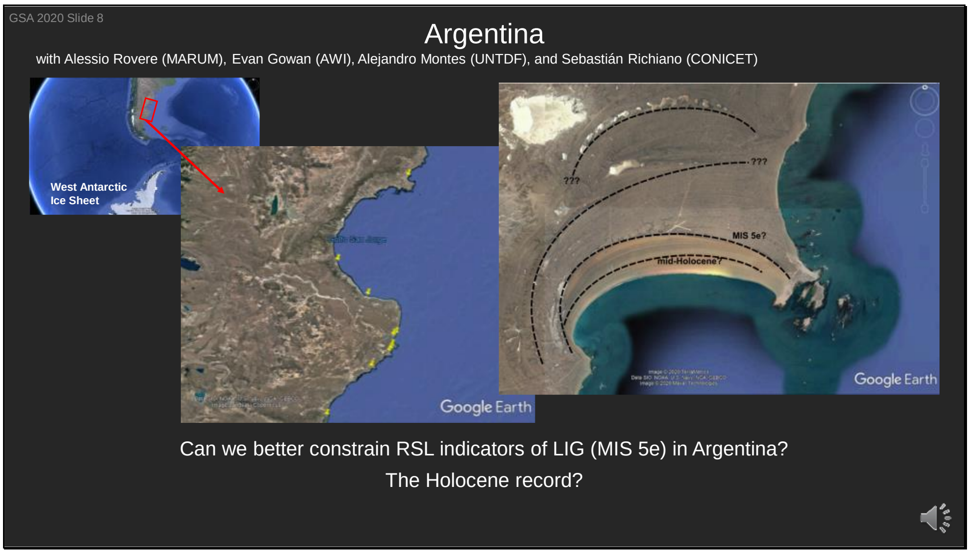

Continuing in the Southern Hemisphere, the relative close proximity of Argentina to Antarctica make it a particularly important region of sea-level study as it is very sensitive to ice volume change in the West Antarctic Ice Sheet. This fieldwork helps to fulfill a WARMCOASTS project aim to collect new field data of sea level indicators spanning the entire Western Atlantic. As you can see in this second image, many phases of deposition are preserved along the coastline – again as prograding beach deposits - representing multiple interglacial highstand sea levels.
We visited quite a few sites that are believed to be last interglacial in age and took numerous transects with high resolution dGPS, but also took time to look at the Holocene record of sea-level.

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The sediments in Argentina are extremely different to those in New Zealand. The beaches are formed of pebbles and cobbles. What is interesting, and makes an excellent indicator of sea level, is that the sediment within the low tide zone, in some locations, is a distinctly different compact fine sand. This shows up very clearly, at this field site, in both the modern and older deposit at the back of the beach where you can see the fine grain sand deposited upon a platform formed in an older Cenozoic deposit. The base of the sand has specimens of articulated bivalve shell. Overlying this unit is the coarser beach and beach ridge sediments also containing shell.
GPR was attempted at multiple locations across Pleistocene and Holocene sequences. However, in the field, it did not look like GPR across the Pleistocene successions was successful and we are guessing it has something to do with sediment composition. Luminescence methods for analyzing sediments of pebble to cobble grain size are still in development and the method is not considered optimal at this time - So I will be conducting amino acid racemization analysis on shell samples to establish a relative geochronology.

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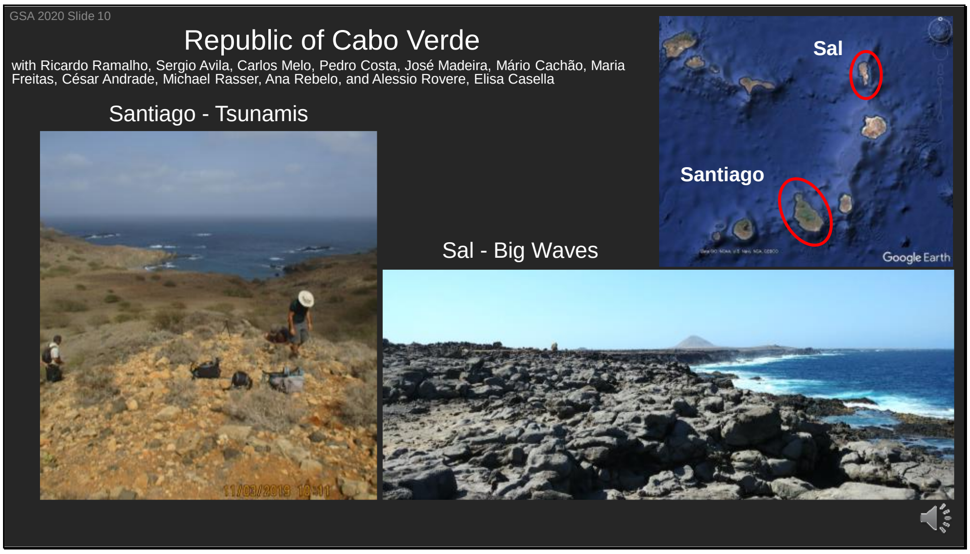

Ok. Moving onto the Republic of Cabo Verde. Cabo Verde is an archipelago of volcanic islands in the eastern Atlantic Ocean. I have looked at possible MIS 5e shoreline deposits on these islands as well, but for the sake of time, and to share some insight into records of more extreme and hazardous events, I'll be focusing on the tsunami and big wave research I've assisted on. On Santiago there is evidence of megatsunami waves over 200 m above present sea level. And on Sal, boulder ridges above marine platforms at ~7 m above sea level indicate periods of increased storm intensity and bigger waves than seen historically. The PI of this work is Ricardo Ramalho but there were a lot of other people involved on these trips.

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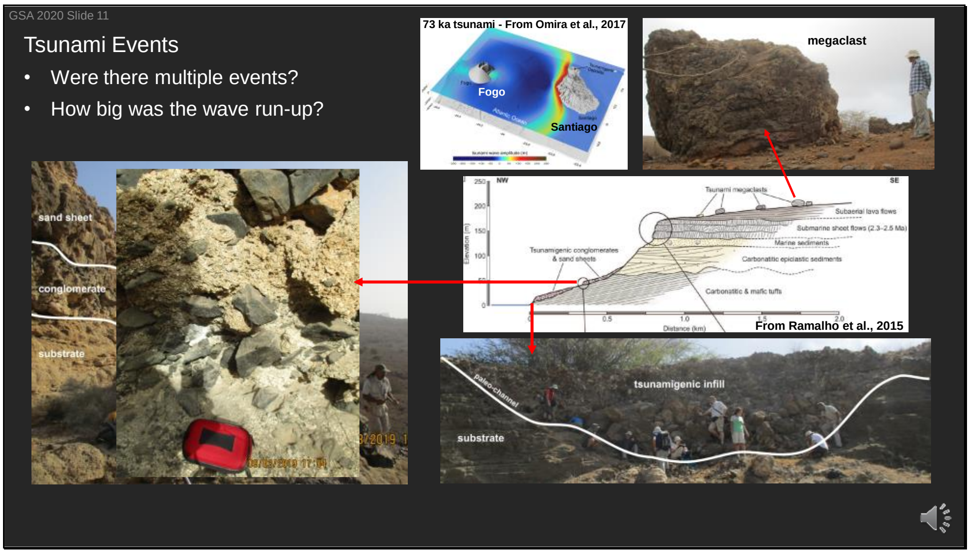

The island of Santiago is located east of the island of Fogo, which is actually a young and active stratovolcano whose last eruption began in Nov 2014 and ended in February 2015. Massive flank collapse ~73,000 years ago triggered a megatsunami that led to the deposition of basaltic megaclasts up to 8 m in diameter on a plateau over 200 m above modern sea level and indicate an incoming wave height of 270 m at the coeval shoreline. Our visit earlier this year was to determine if the conglomerates and sand sheets on the slopes below the plateau were from one or multiple events and to map the altitude of those deposits.
Additional megaboulders were sampled for cosmogenic dating to determine exposure ages. The conglomerates are a chaotic mixture of marine and terrestrial materials with a matrix of bioclastic sandstone. Fossil samples were taken to examine paleo-ecology and determine if multiple environments were represented. Resolving whether or not multiple tsunami events are present and possibly the associated wave run-up will help with determining the frequency and severity of tsunami events due to Fogo flank collapse.

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Our warming climate is leading to increased frequency and intensity of extreme climatic events. One question that has been debated is whether or not the changing climate will also lead to bigger waves and storms more intense than recorded historically. The boulder ridges on Sal, if correlated with the LIG, may help us to answer if we can expect greater wave intensity in our warmer world.

The boulder ridges are located at the top of a plateau and on the landward margin of marine terraces. Large clasts of this coral reef terrace are located above and landward of the reef remnants constraining deposition of the boulder ridges to post-reef deposition. The age is being constrained in two ways. In situ coral is being dated to determine a maximum age and exposure ages were taken from the basalt boulders. We also did a number of drone flights along the beach ridges and expect to have high resolution photogrammetry of this section of the coastline.

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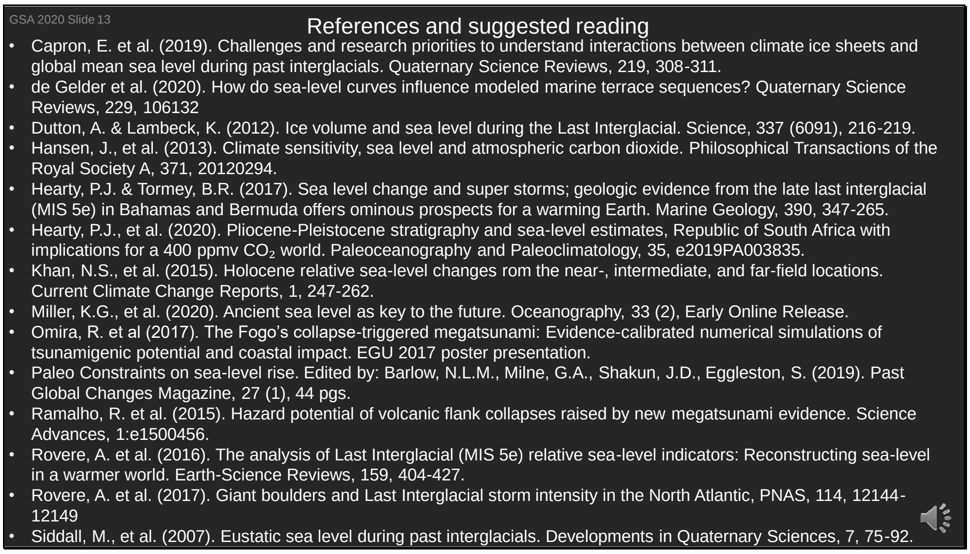

Ok, finishing up here. This slide provides a list of references I have used or referred to in the making of this presentation.

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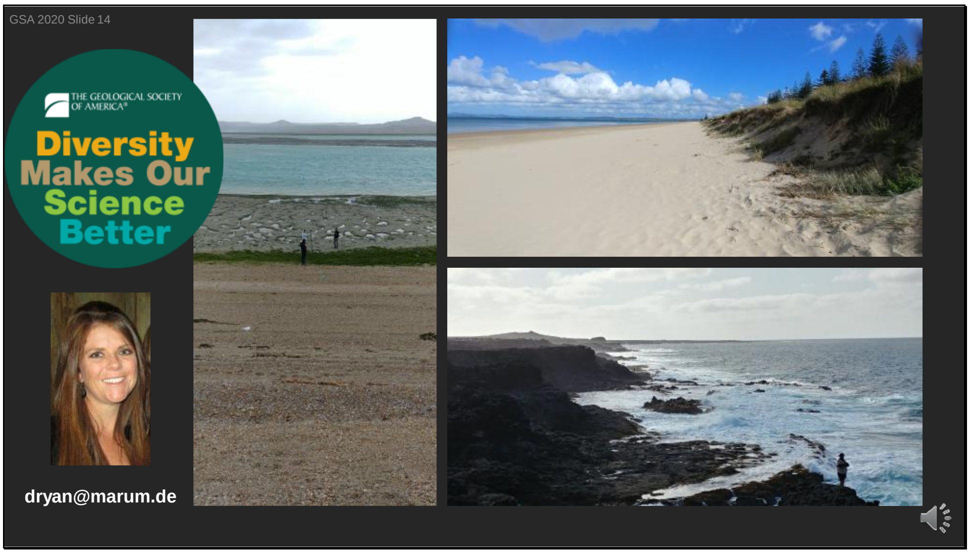

And finally, it’s not only a diversity of coastlines that makes our science better, a diversity of scientists does as well. I’m pleased to see the increased awareness, discussion and events with regards to DEI throughout 2020 and across so many platforms.

Thank you for your time. I’m happy to take your questions during the virtual session or you can contact me via email at dryan@marum.de.