AntARctica: An Immersive 3D Look into Antarctica's Ice Using Augmented Reality and Virtual Reality

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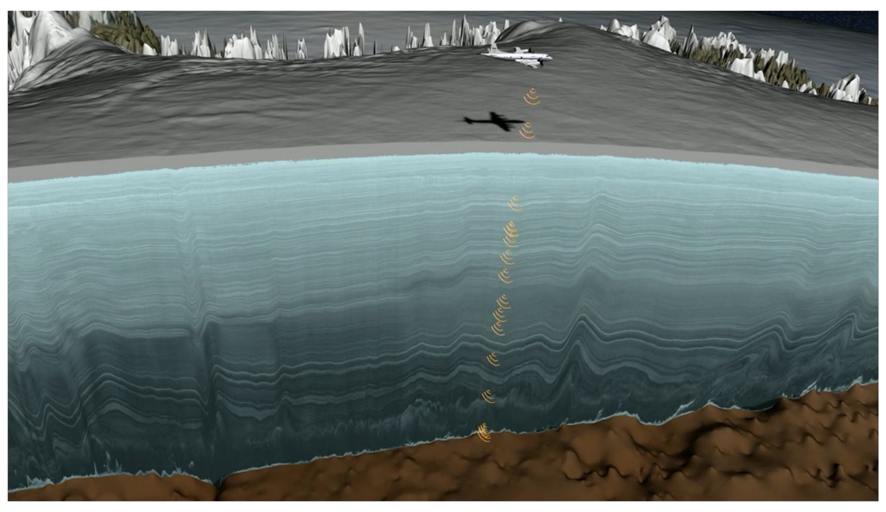
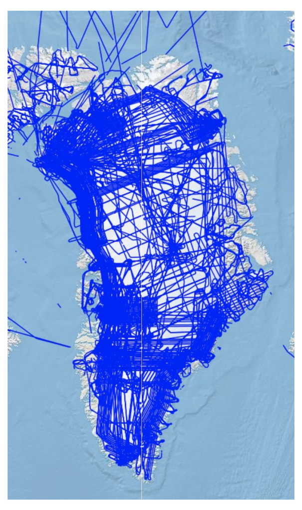
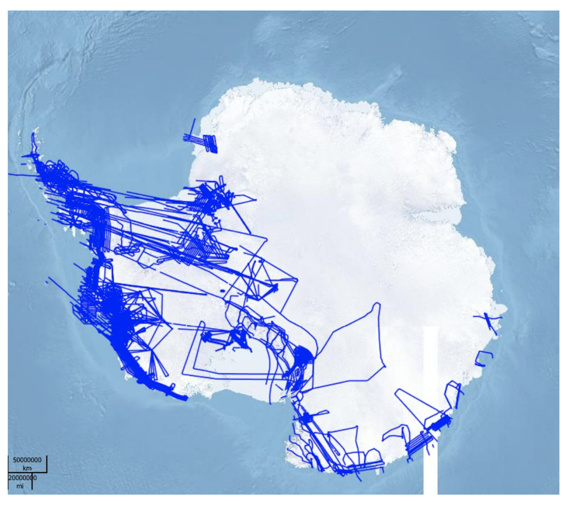
Ice-penetrating radar data have been collected across Greenland and Antarctica for decades and allow us to peer inside the ice.







Left: Schematic of airborne ice-penetrating radar being collected across the Greenland Ice Sheet (National Aeronautics and Space Administration (NASA) Visualization Studio). **Middle:** Locations of radar data collected (blue lines) across the Greenland Ice Sheet from 1993 to 2021 (Open Polar Server, made by the Center for Remote Sensing of Ice Sheets at the University of Kansas). **Right:** Locations of radar data collected (blue lines) across the Antarctic Ice Sheet from 1993 to 2021.

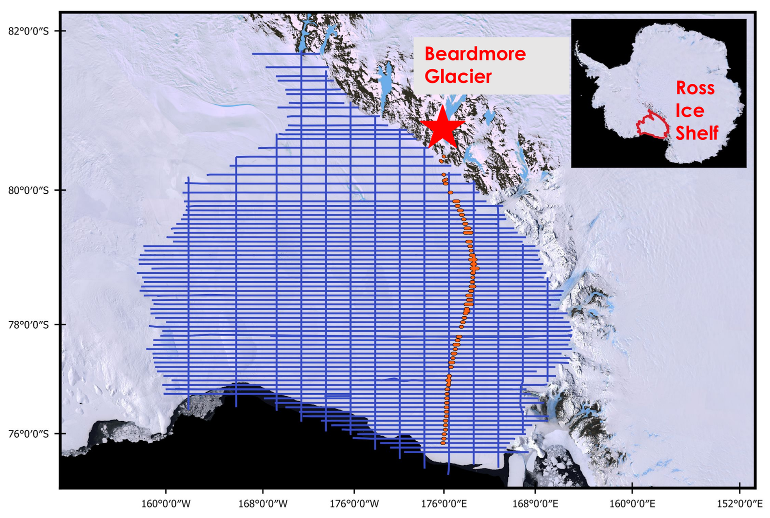
Augmented Reality (AR) combines your experience of the physical world with a virtual world, while **Virtual Reality (VR)** replaces your experience of the physical world with a virtual world.

Left: The Microsoft HoloLens2 AR headset. Users manipulate virtual objects projected into the physical world with hand gestures and voice activation. **Left:** The Meta Quest2 headset and controllers (white) and Meta Quest Pro headset and controllers (black). Users manipulate virtual objects with controllers and voice activation. These headsets can be used as AR devices as well as immersive VR devices, as their camera systems can be used to render the physical environment as well as virtual objects.

ROSETTA-Ice Radar Data (ROSETTA SIR)

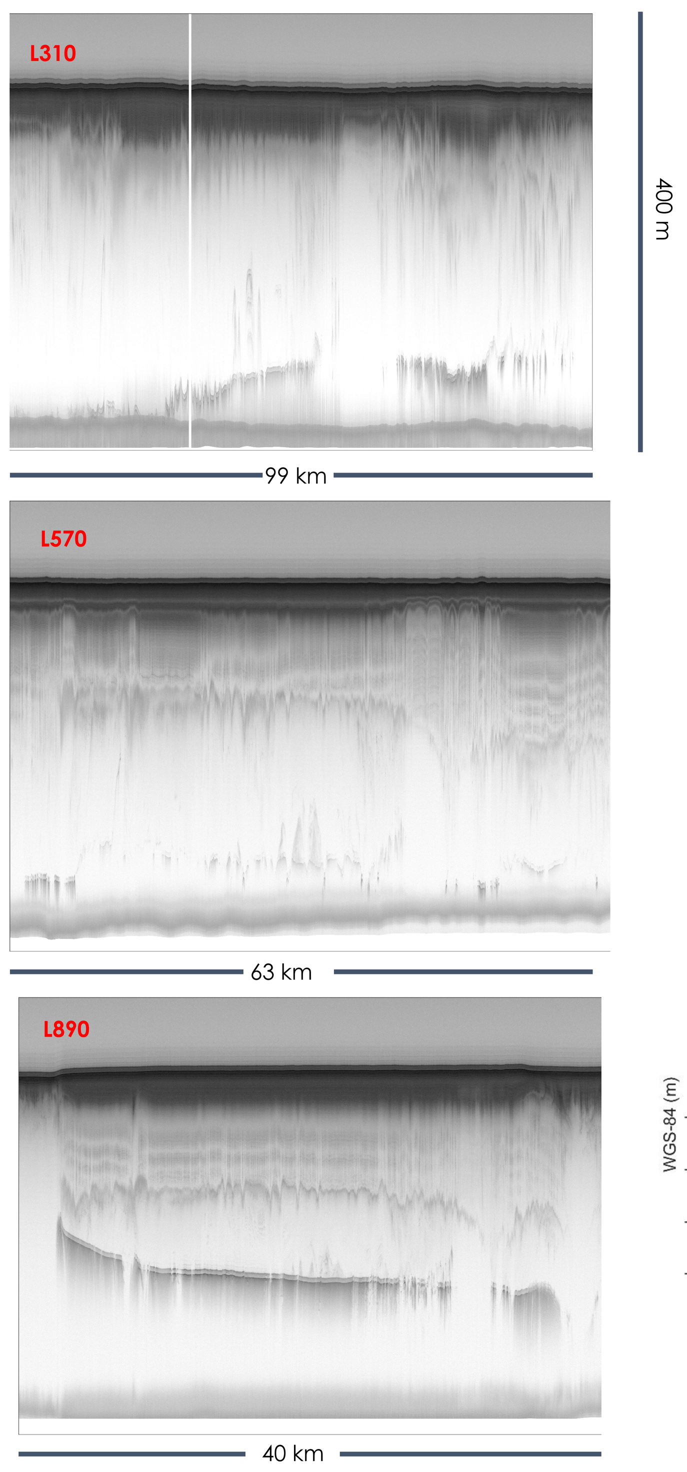
The ROSETTA-Ice project was an airborne geophysical campaign that mapped the Ross Ice Shelf using the IcePod system from 2015 to 2017.

Right: Map of all ROSETTA-Ice flightlines (blue) against the Landsat Image Mosaic of Antarctica basemap. Red lines show the radar frames included in AntARctica. The subset was chosen based on the identification of a persistent features in the base of the ice that can be traced from the Beardmore glacier (red star) all the way to the front of the ice shelf. Inset map shows the Ross Ice Shelf outlined in red.



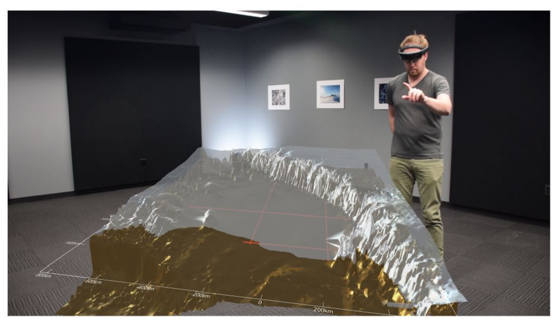
Right: Three SIR echograms collected by the ROSETTA-Ice project. Lines 310, 570, and 890 show the surface and base of the ice, along with an internal horizon discussed in Tinto et. al, 2019, and Das et al. 2020, and a basal reflector, referred to as the Beardmore Basal Body.

Above: The IcePod system installed on an LC-130 in Greenland, 2014. The IcePod has two radar systems: a Shallow Ice Radar (SIR) that images the upper layers of the ice, and a Deep Ice Radar (DICE) that images the full ice thickness.

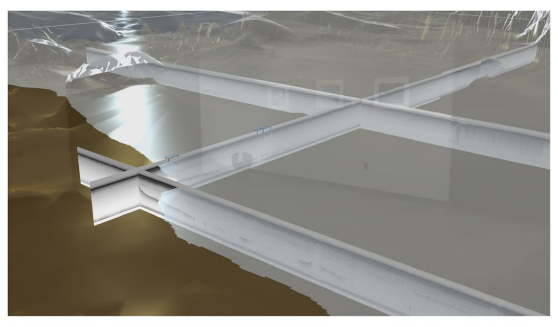


Right and below: Views of Inside the Ice Shelf application for the HoloLens (Boghosian et. al, 2019). **a)** Ross Ice Shelf scene in use. Digital Elevation Models (DEMs) of the ice surface (white) and sub-ice topography and bathymetry (brown) shown along with flight lines (red) **b)** ROSETTA radar lines shown in context with DEMs **c)** ROSETTA radar lines shown in detail with picks (red) and regions of interest to zoom into (blue).

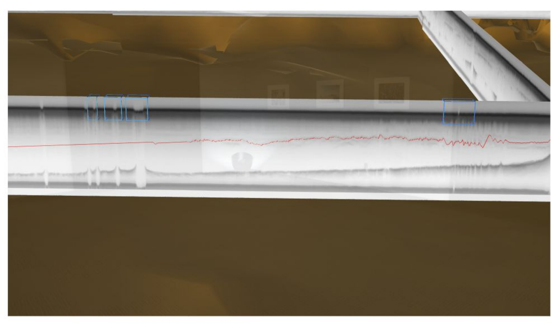
a) Ross Ice Shelf Scene



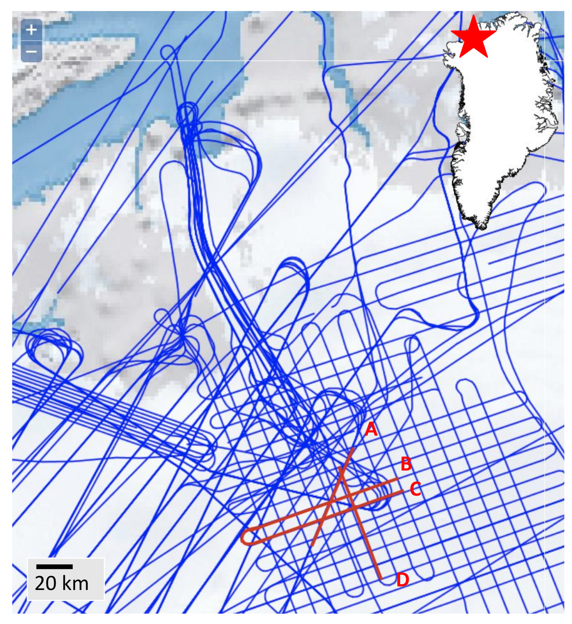
b) ROSETTA-Ice Radar



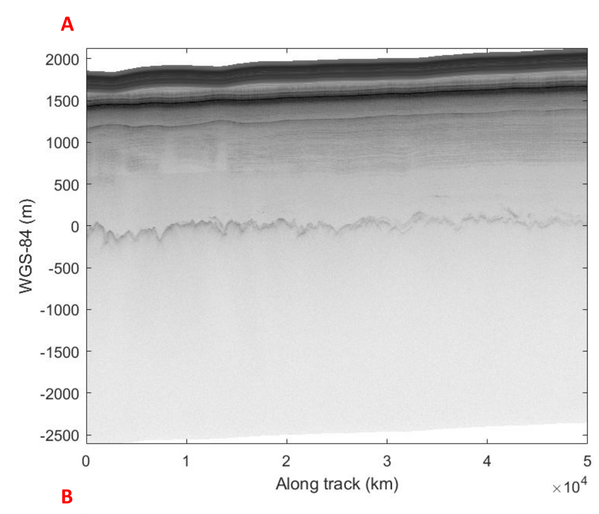
c) ROSETTA-Ice Radar detail



Operation IceBridge Radar Data (MCoRDS)

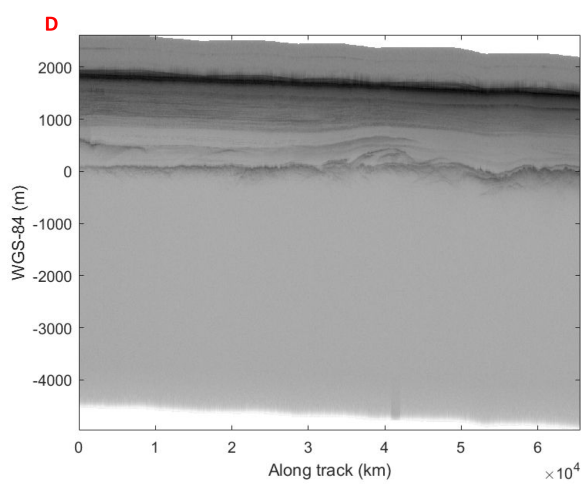


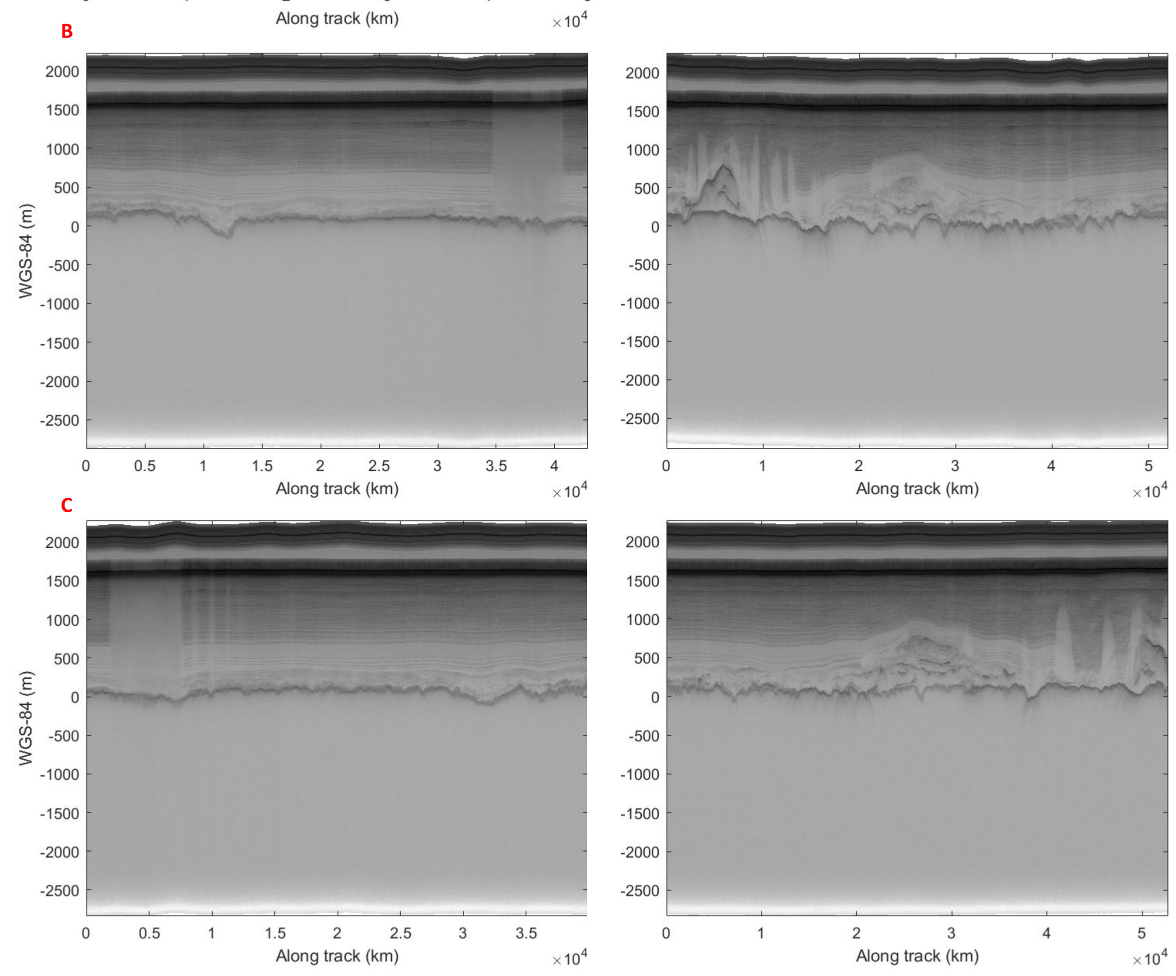
Above: Map from the Open Polar Server showing all OIB flights around the Petermann Glacier region (blue). Inset map shows the Greenland coastline and region of interest (red star). Red lines show the locations of MCoRDS radar echograms pictured to the right and below. The grid was collected in 2010 and 2011 and has revealed basal structures, created by different thermal regimes that deformed the otherwise horizontal stratigraphy (Bell et. al, 2014; Wolovick et. al, 2016).



Operation IceBridge (OIB) was an airborne campaign that surveyed the land and sea ice in the Arctic, Antarctic and Alaska from 2009 to 2021. OIB instruments included the Multichannel Coherent Radar Depth Sounder (MCoRDS) system that imaged the base and internal structure of the Greenland and Antarctic Ice Sheets.

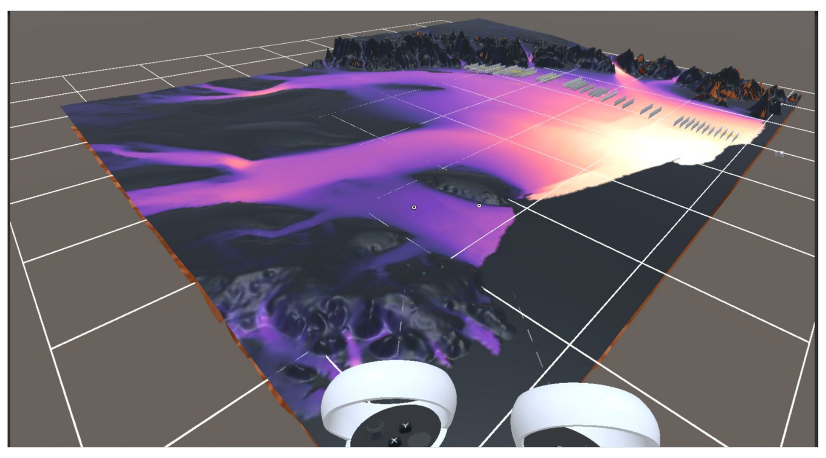
Left and below: MCoRDS echograms shown for lines denoted on the map. **A** shows data collected at an oblique angle to the grid in 2019, **B and C** show data collected in 2011. **B** is the northern line and **C** is the southern. We show the data in two frames in the E/W orientation. **D** shows data collected along a N/S portion of the grid collected in 2010.



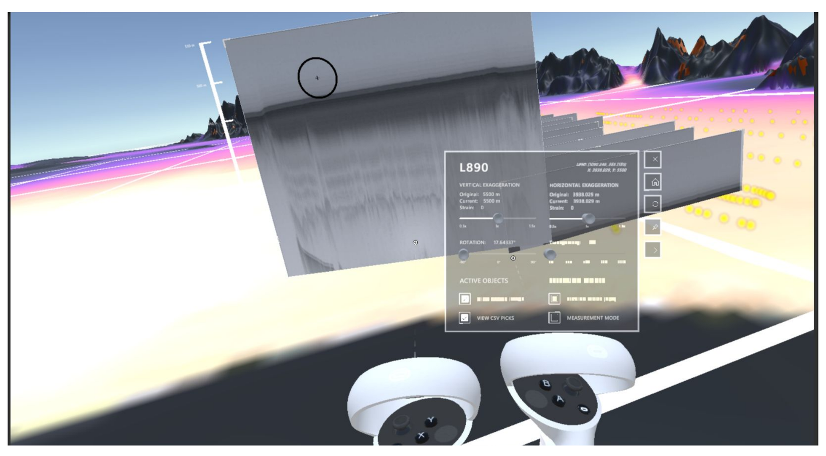


POL-AR/VR: an AR/VR application that allows users to visualize, analyze and measure ice penetrating radar data

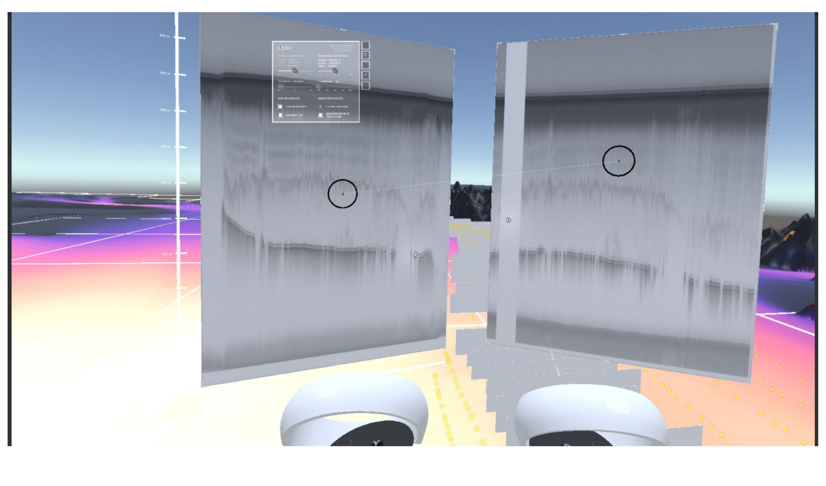
Try POL-AR/VR on the HoloLens2 and Meta Quest2, and learn more from **Ben** and **Shengyue** at the **AGU Student Visualization Competition**
Wednesday 12/14 at 12 pm CST
Hall A- NASA Booth 1937 (South, Level 3)



Development view of AntARctica showing Quest2 controllers and the Ross Ice Shelf DEMs from BedMap2 (black and brown are ice surface and base) textured with ice velocity data from the MEAsUREs project. Gray planes show the ROSETTA radar echograms.



Development view of AntARctica highlighting radar data and interactions. Here L890 has been moved from its original position to be analyzed separately. Quest2 controllers and MEAsUREs velocity also shown. Yellow dots show surface features identified on the ice by LeDoux et al. 2017. These appear to track the Beardmore Basal Body.



Development view of AntARctica highlighting radar data acomparison. Here two radar echograms are being compared side by side. Scale bars and axes pop up with the image. Black points and line show the user measuring distance.

Analysis Tools

- Strain calculations appear on the menu as users stretch radar images
- Thickness measurements can be made by selecting two points on a radar image. This measurement tool can be also be used across radar echograms.
- Feature snapping allows radar images to be compared more accurately. Transparency lets users identity features in multiple images.
- Feature identification, selection, and tracking can be done by drawing points on images

Intuitive Interactions

- Interact with objects using the Quest2 triggers on the handsets, or on the HoloLens 2 by pinching your index fingers and thumbs together.
- Walk through the environment and tilt your head to see beneath the surface DEM to see radar images of the interior of the ice shelf.
- Select and move a radar image to view it more closely. Stretch, scale, and compare each radar image to your preference using handsets (VR) or gestures (AR).

Menu Items:

Vertical Exaggeration:
View the original height of the radar image (in meters), the current stretched height, and calculated strain rate (in meters).
Users have the option to use the slider to stretch the image, instead of using motion controls.

Rotation:
View the current rotation of the radar image.
Users have the option to use the slider to rotate the image on a horizontal axis, instead of using motion controls.

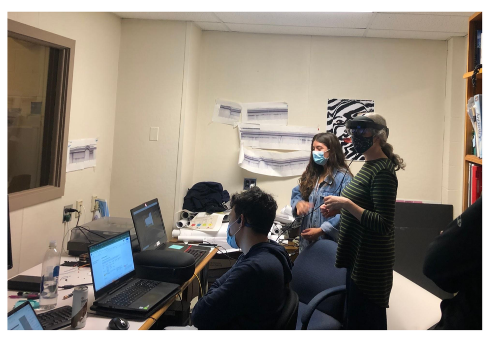
Horizontal Exaggeration:
View the original extent of the radar image (in meters), the current stretched extent, and calculated strain rate (in meters).
Users have the option to use the slider to stretch the image, instead of using motion controls.

Transparency:
Users can enable transparency on a radar image to compare parallel images by using the transparency slider to change the opacity.

Active Objects:
Toggle visible objects within the environment, on or off.
Users may turn "off" a radar image or its associated digitized thickness or surface rendered into a CSV from manual horizon picking.

Selection Modes:
Users may enable a Picking Mode, which allows a measurement and snapping of a specific feature. [DEV]
Measurement Mode enables the user to measure the distance between two points they make.

Voice Commands:
"Menu" displays the menu screen
"Measure" brings up the measurement tool
"Go" enables users to teleport to a selected radar image
"Box" enables users to mode to scale and move the entiren scene
"Reset" resets the scene



Left Scientists developing AntARctica and using the HoloLens2 to view and analyze radar data. **Right** User exploring radar data with AntARctica on the Quest2 at an outreach event

Future Work

Geolocation improvements:
Generating more accurate radargram rendering by exporting radar data as object files (OBJ) will provide more precise geospatial context. This will also streamline the application development process. The ROSETTA-Ice radar will be represented with respect to the WGS 84 ellipsoid in future versions of this application.

Immersive 3D picking:
Support horizon picking in the AR/VR application with the ability to export ASCII or CSV outputs. This will allow users to have access to the full 3D spatial context that they need to interpret structures visually, as opposed to building 3D structure in their mind's eye from 2D images and maps.

Implementation of OIB radar:
We aim to put as much radar into AR/VR as possible, and will build our next scene to include data collected around Petermann Glacier.

User study:
MCoRDS data have been analyzed and digitized. We plan to perform basic radar picking in the AR/VR environment and determine whether interpretation changes with the addition of 3D immersive tools.

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