Remote Sensing of Earth's Cryosphere with 0.5-2 GHz Microwave Radiometry: Recent Updates

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MOTIVATION

Recent works have demonstrated the utility of 0.5-2 GHz microwave radiometry for monitoring Earth's ice sheets, ice shelves, and sea ice. The use of frequencies lower than 1.4 GHz enables the reception of information from deeper within the ice medium. This in turn can enable the sensing of the physical temperature profile within an ice sheet and improve the sensing of sea ice thickness. These results have supported the development of the CryoRad and PolarRad mission concepts for future flight in space.

Here we perform further examinations of 0.5-2 GHz airborne measurements of Priestley Glacier, Antarctica with a particular focus on factors influencing the spectral behaviors obtained in these measurements.

UWBRAD

The dataset examined was acquired by the UWBRAD instrument that provides brightness temperature observations from 0.5-2 GHz using multiple frequency channels. Because these are unprotected portions of the radio spectrum, radio frequency interference (RFI) is a major issue. Measurements are performed by sampling the entire bandwidth into 12 frequency channels so that advanced RFI detection and mitigation methods can be applied in real time. This process enables UWBRAD to identify open portions of the spectrum that can be used for radiometric observations even in the presence of other transmitting sources.

Frequency	0.5-2 GHz, 12 x ~ 81 MHz channels
Polarization	Single (Right-hand circular)
Observation angle	Nadir
Spatial Resolution	~1.2 km x 1.2 km (1 km platform altitude)
Integration time	100 msec
Ant Gain (dB) /Beamwidth	10 dB 60° (two-sided)
Calibration (Internal)	Reference load and Noise diode sources
Calibration (External)	Ocean Measurements
Noise equiv dT	~1 K in 100 msec (each channel)
Interference Management	Full sampling of 100 MHz bandwidth in 16 bits resolution in each channel; real time "software defined" RFI detection and mitigation

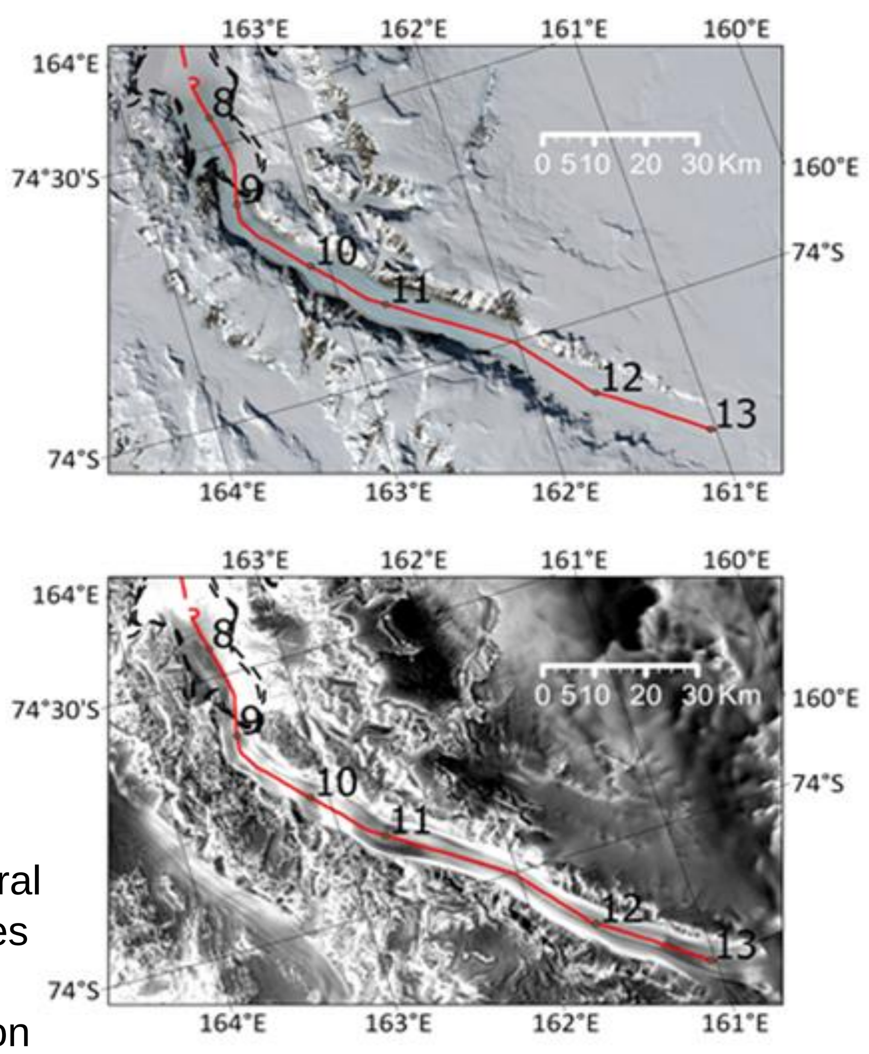
UWBRAD was deployed over Greenland in 2016 and 2017 and in Antarctica in November-December 2018. The latter observations from the "ISSIUMAX" campaign are of interest here. These campaigns have demonstrated the potential of using UWBRAD for ice sheet internal temperature measurements and also for other cryospheric applications such as sea ice thickness retrieval.

ISSIUMAX PRIESTLEY GLACIER FLIGHT

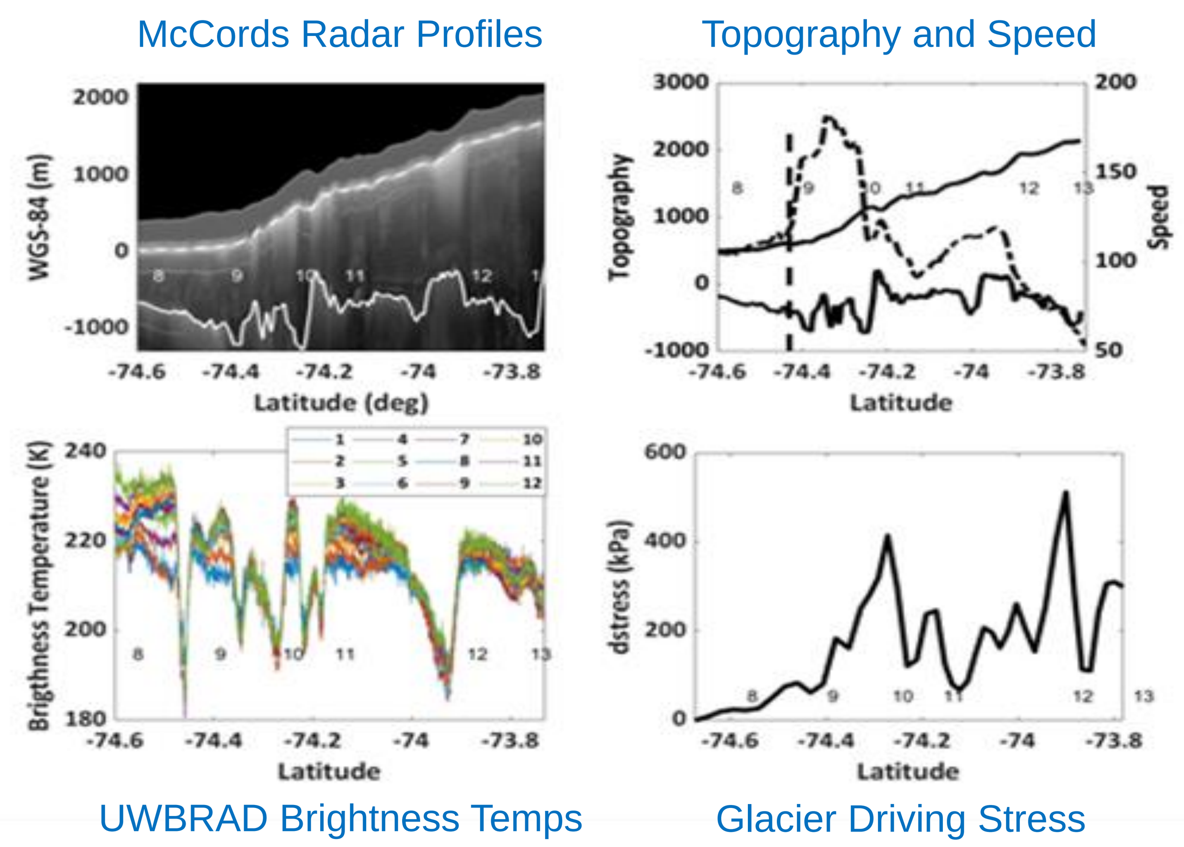
The airborne radiometer dataset was acquired November 25, 2018 during the Ice Sheet and Sea Ice Ultrawideband Microwave radiometric Airborne eXperiment (ISSIUMAX), a collaboration of the Institute for Applied Physics in Florence, Italy and Ohio State. The ISSIUMAX flight path was collocated with OIB datasets collected 5 years previously.

ISSIUMAX included multiple flight days over coastal sea ice, inland ice, and other locations; of interest here is the track over Priestley Glacier shown to the right.

The path spans several distinct glacial regimes beginning from the floating terminal region of the glacier that then extend upstream through the Transantarctic Mountains and onto the inland ice sheet. This range of glaciological regimes and surface properties provides an opportunity to investigate reflection and emission processes in each location and to obtain insights into the glaciological properties that can be inferred.



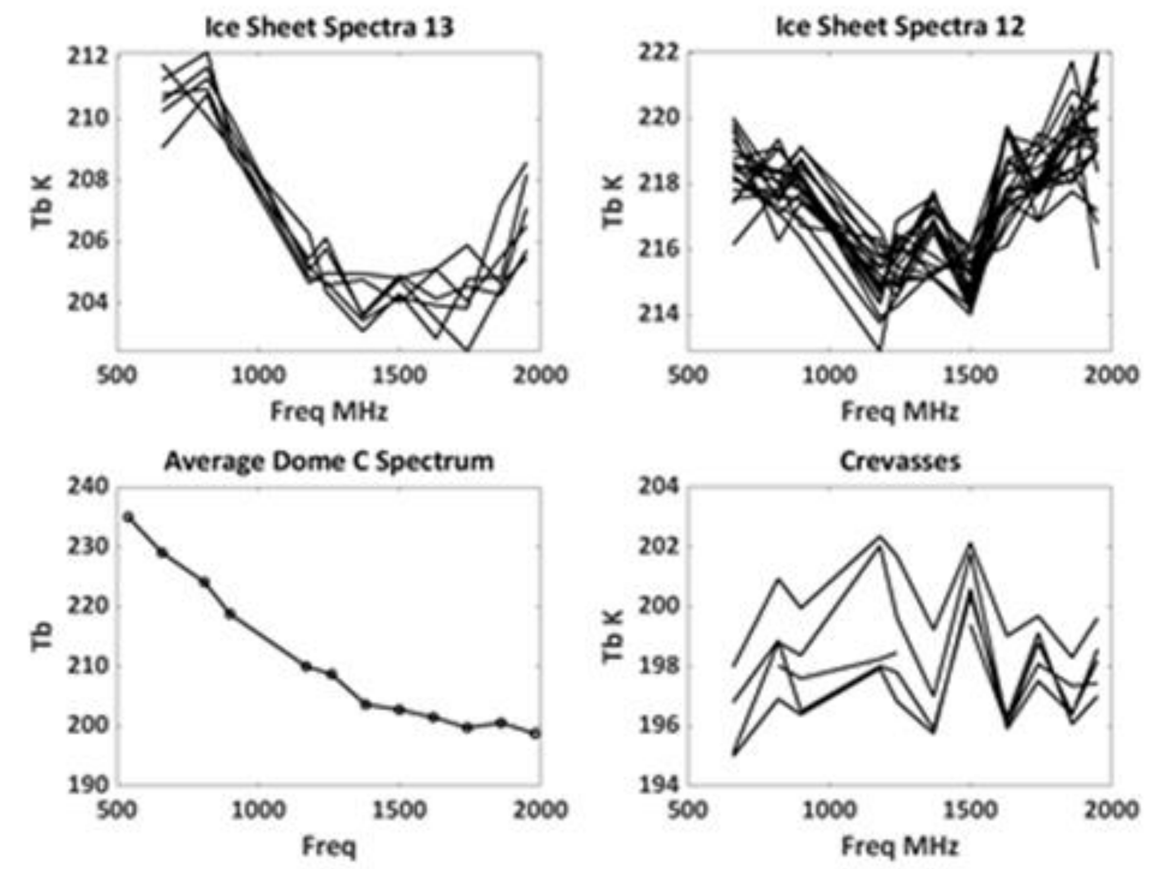
ISSIUMAX data collection on Radarsat 1997 Antarctic mosaic (lower) and Landsat image 06/13/2018 (upper). Red line marks data set studied here.



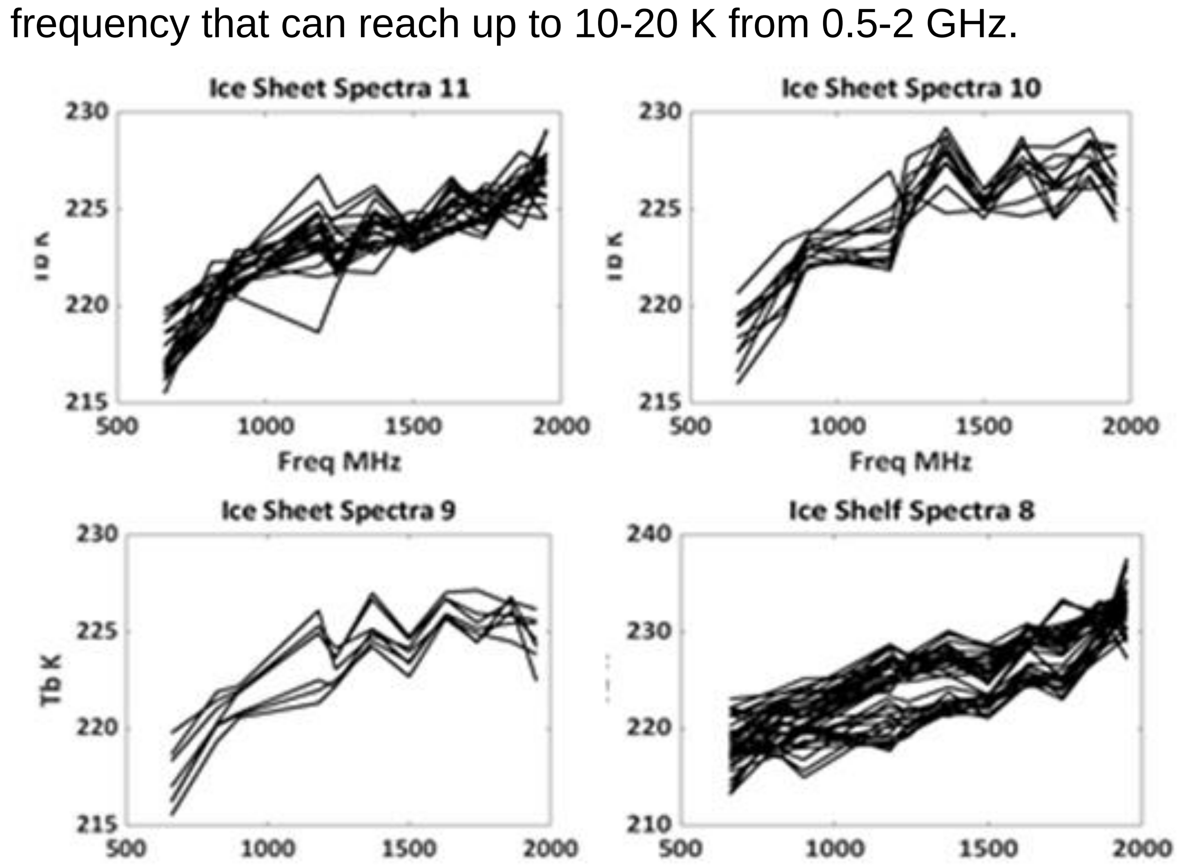
BRIGHTNESS TEMPERATURE SPECTRA

The spectral properties of the brightness temperatures observed are of key interest. Past studies have shown that brightness temperatures tend to increase in frequency for "sea ice"-like targets and to decrease with frequency with "ice sheet"-like targets.

The spectra shown below for sites 12 and 13 (most upstream locations) show decreasing spectra generally consistent with "ice sheet" like behaviors as observed previously near Dome-C (lower left). The lower right plot illustrates the greatly reduced brightness temperatures that can occur in highly crevassed regions (Tb minimum between sites 10 and 11); such regions are excluded from further analysis in this work.



In contrast, spectra from sites 8-11 show an increasing trend in frequency that can reach up to 10-20 K from 0.5-2 GHz.



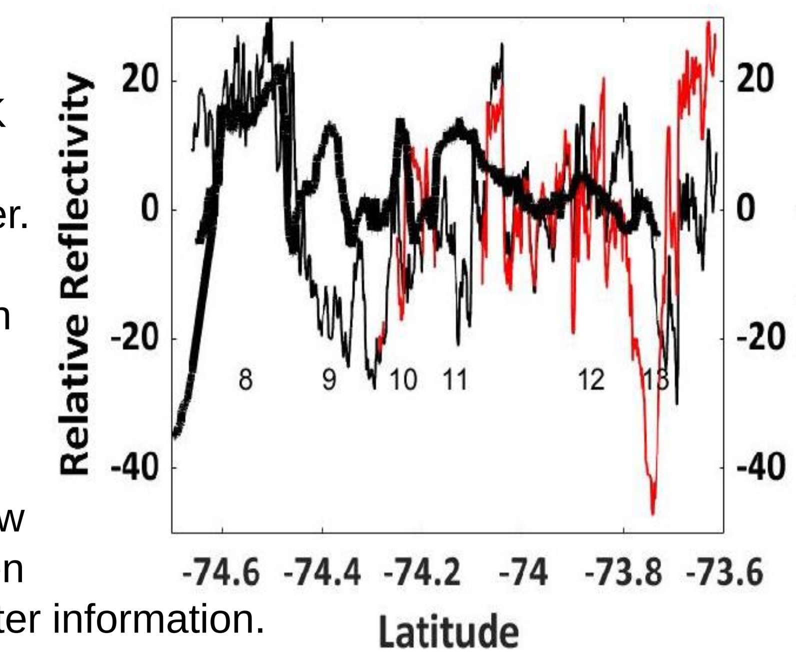
ANALYSIS OF RESULTS

The "early" arrival of the sea-ice like spectra beginning at Site 11 is somewhat surprising given the upstream location of this site. One hypothesis is that water located at the glacier bed causes these effects. To examine this hypothesis, the McCords basal reflectivity along the flight path was extracted as shown below in thin black and red and compared to the increase in brightness temperature from 560 to 1950 MHz (thick black).

Reflectivity> 10 dB + Tb change >10 K can be used to indicate basal water.

Sites 8 and 10 both show evidence of basal water.

Sites 9 and 11 show differences between radar and radiometer information.



Both the radar and radiometer data at site 12 also support interpreting site 12 as a transition zone. Complex basal topography, strong internal layers to nearly the ice bottom, and crevasses may complicate these interpretations as well.

SUMMARY

The examined MCCoRDS reflectivity and UWBRAD brightness temperatures show plausible evidence of a transition from frozen-base ice sheet conditions to patchy wet-base conditions beneath the outlet glacier. The locations where patches of basal water are identified coincide with low values of the driving stress consistent with locally lower basal drag. This interpretation is further supported by geothermal heat flux modeling of Priestley Glacier which tested the sensitivity of either dry or wet based conditions to combinations of glacier speeds and heat flux values

The analysis illustrates the use of active and passive microwave observations to investigate subglacial conditions associated with the complex flow of outlet glaciers. The results are important for the continuing development of 0.5-2 GHz microwave radiometry for monitoring Earth's cryosphere.

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