ULTRA-WIDEBAND RADAR MEASUREMENTS OF SNOW THICKNESS OVER SEA ICE

Ben Panzer, Carl Leuschen, Aqsa Patel, Thorsten Markus[1] and Prasad Gogineni

Center for Remote Sensing of Ice Sheets (CReSIS), University of Kansas
[1]Laboratory for Hydrospheric Processes, NASA/Goddard Space Flight Center

1. INTRODUCTION

Snow cover over sea ice modulates ocean-ice-atmosphere interactions. Snow acts as an insulator because of its low thermal conductivity and alters temperature profile. It also acts as a mechanical load to change ice freeboard. Information about snow thickness over sea ice is required to improve global climate models and estimates of sea ice thickness from freeboard measurements performed with airborne and satellite altimeters [1]. We developed an ultra-wideband radar for operation on long-range aircraft to directly measure snow thickness over sea ice. We have successfully used this system to collect data over Arctic and Antarctic sea ice during the last year.

2. RADAR DESCRIPTION

The ultra-wideband radar described is an improved version of our earlier systems [2-5]. The modifications and improvements enable operation from a fast-moving long-range aircraft. Figure 1 shows a high-level block diagram of the ultra-wideband radar.

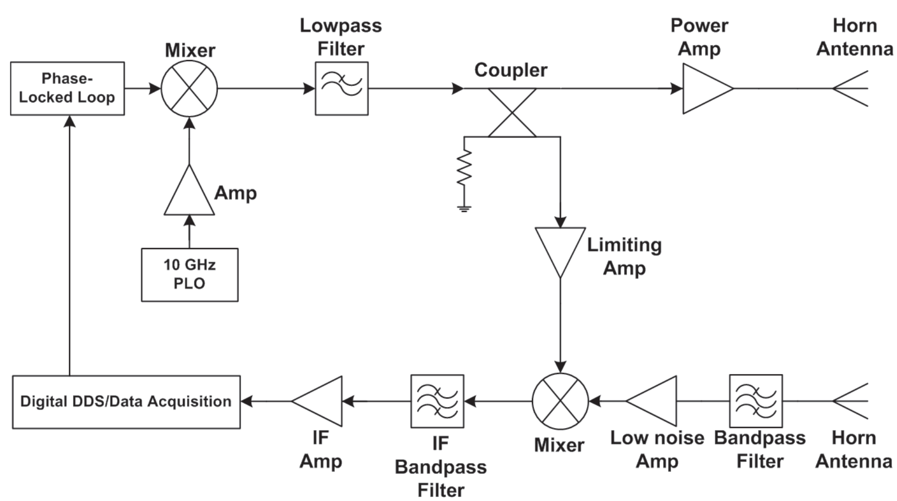

Figure 1 – Block diagram of the ultra-wideband radar

A 214-295 MHz baseband chirp is generated by the direct digital synthesizer with a 240-µs pulse length and 2.5 kHz pulse repetition frequency. The baseband chirp is input to a phase-locked loop, with a factor of 56 up-conversion, which outputs a 12.0-16.5 GHz chirp. The 12.0-16.5 GHz chirp is mixed with a 10-GHz phase-locked reference with the lower sideband of 2.0-6.5 GHz preserved and filtered. Part of the transmit signal is input to a directional coupler, followed by amplification by means of a limiting amplifier and input to the LO port of the receiver mixer. The remainder is amplified and transmitted with an average output power of 23 dBm (200 mW).

The receive signal is filtered and amplified prior to input to the RF port of the mixer. Mixing the received signal with a copy of the transmit signal results in an intermediate frequency, or beat frequency, that is proportional to the range to target, or in this case the air/snow and snow/ice interfaces. The resulting beat frequencies, given the nominal radar parameters and cruising altitude of the aircraft, are in the frequency range of 28-58 MHz. Range variations of +/-500 ft can be tolerated without changing waveform parameters. Intermediate frequency signals are filtered with Gaussian, band-pass filters and amplified for digitization. Output rate from the data acquisition system is 20 MB/s.

3. EXPERIMENT RESULTS

Five sea-ice flights were flown for the 2009 Operation Ice Bridge (OIB) Arctic campaign. The flight lines for the Arctic campaign are shown in Figure 2. Representative data for the April 2nd flight line can be seen in Figure 3. Post-processing of the raw data, at the moment, consists of windowing the return signals of interest, pulse compression, and coherent integration.

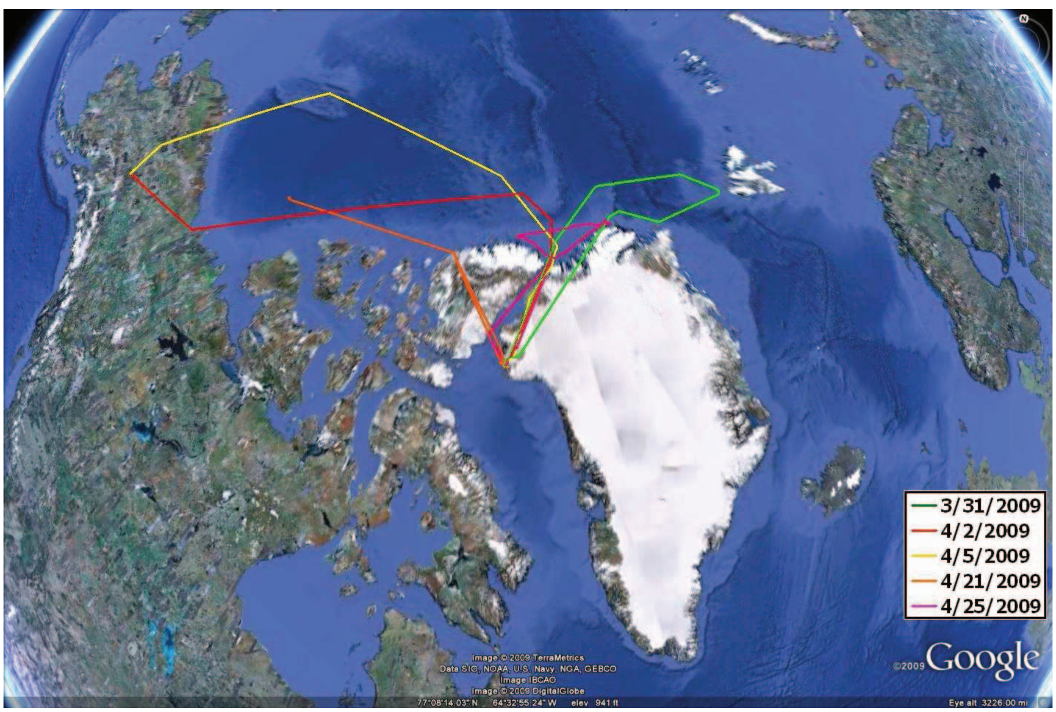

Figure 2 – OIB 2009 Arctic sea ice flight lines

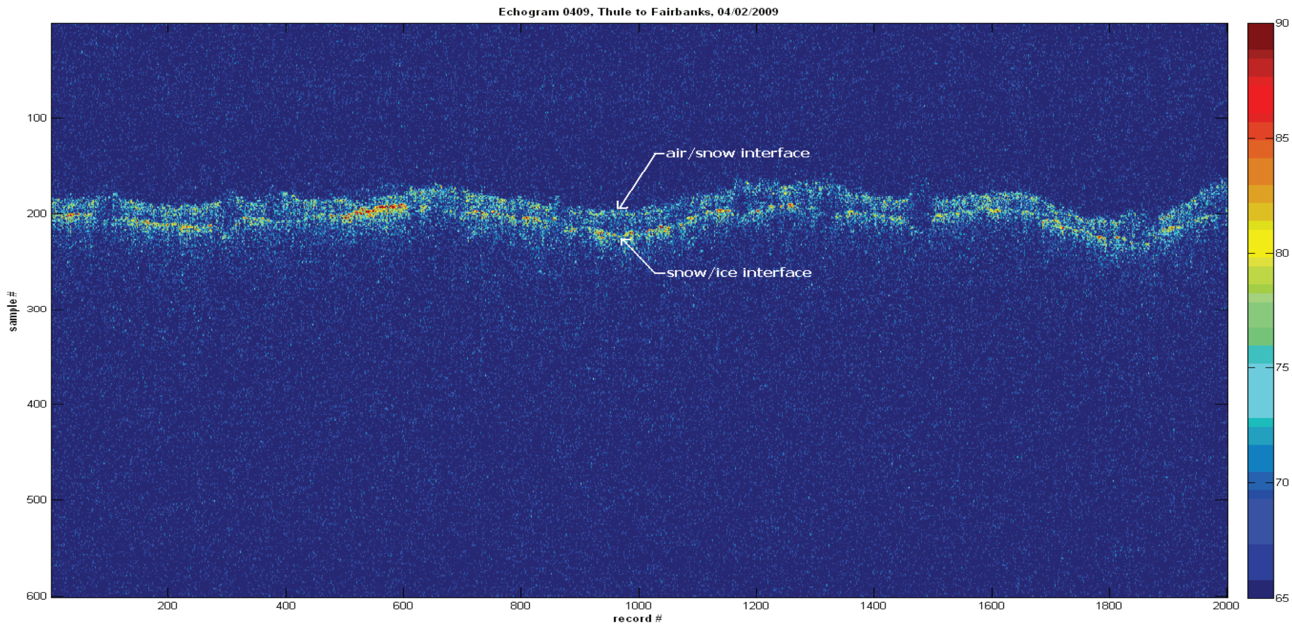

Figure 3 – Echogram 0409, Thule - Fairbanks, 04/02/2009

Three sea-ice flights were flown for the 2009 OIB Antarctic campaign. Due to complications the transmit and receive antennas for the radar were housed in a 16 in diameter laser port. As a result, we operated the radar over the frequency range of 4-6 GHz with a sweep duration of 130-220 µs. Flight lines and representative data for October 24th are shown in Figures 4 and 5. Post-processing of raw data remains the same.

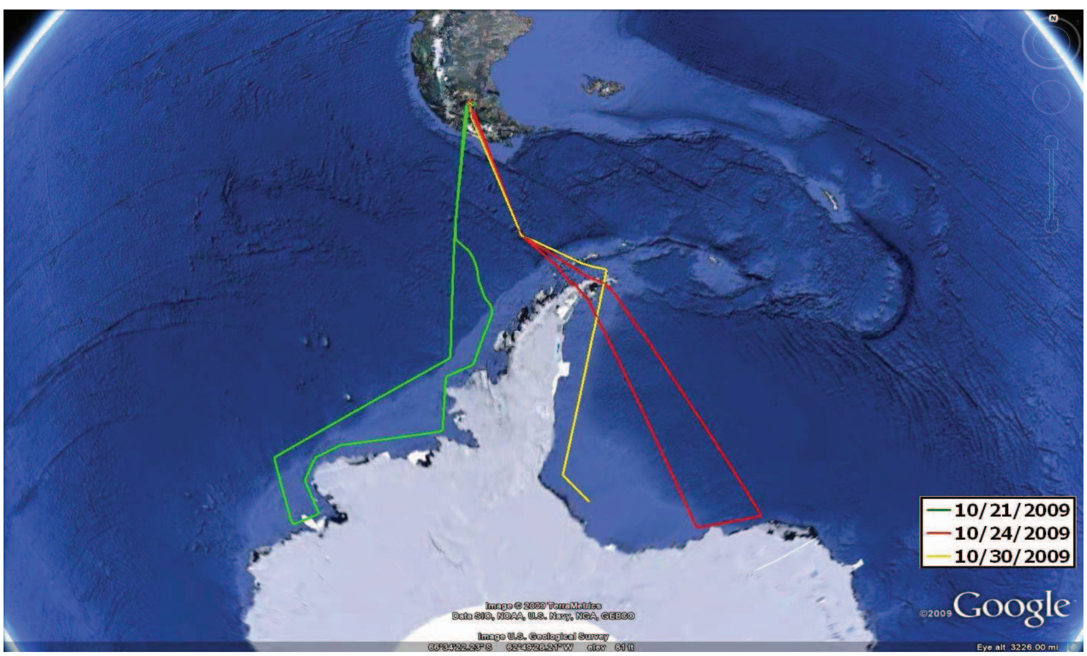

Figure 4 – OIB 2009 Antarctic sea ice flight lines

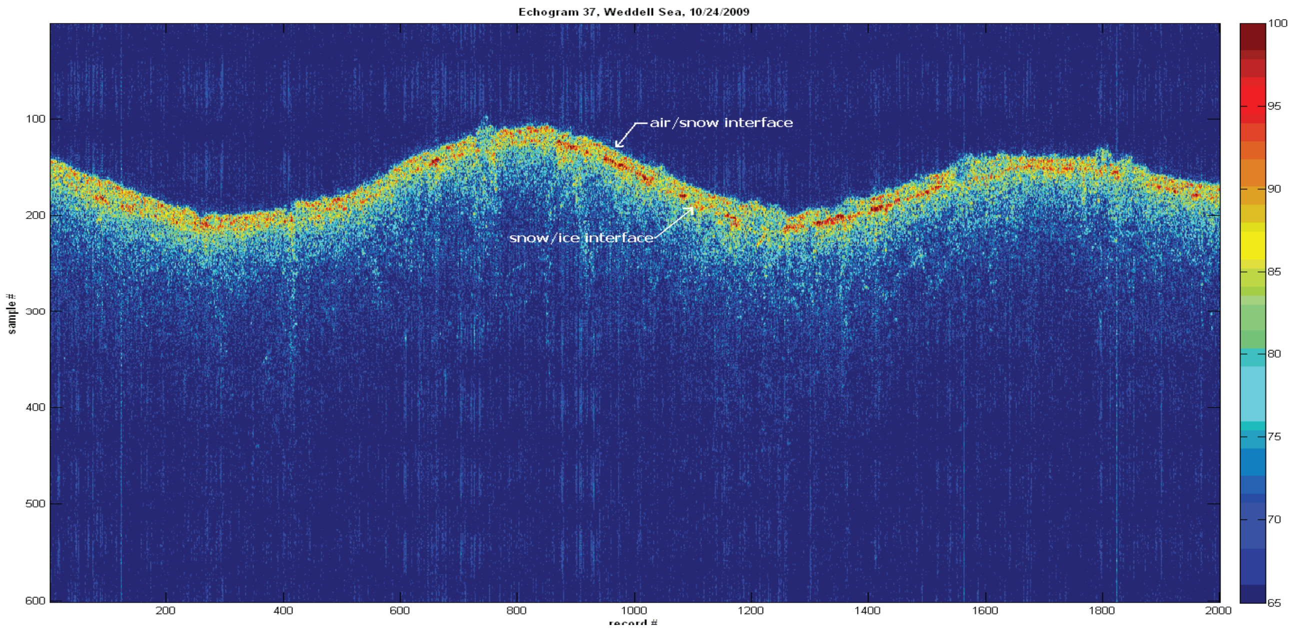

Figure 5 – Echogram 0037, Weddell Sea, 10/24/2009

4. CONCLUSIONS

For the 2009 OIB Arctic campaign, 1.3 TB of data were recorded for 5 sea-ice flights. For the 2009 OIB Antarctic campaign, 1.2 TB of data were recorded for 3 sea-ice flights. Data are currently being processed to generate range profiles as a function of distance along the flight path. These range profiles will be inverted and compared with any available in-situ snow measurements.

In this paper we will discuss modifications and improvements performed to develop an operational airborne radar for snow thickness measurements, provide a brief summary of the field program and processing techniques, and present experimental results.

5. REFERENCES

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