# COMNAP/SCAR Fellowship Progress Report

**Host Institute:** University of Texas Institute of Geophysics (UTIG), University of Austin, Texas
**Host Institute Collaborators**: Prof. Don Blankenship, Dr. Jamin Greenbaum, Dr. Cyril Grima
**Home Institute**: Department of Geography, Dunedin, University of Otago (UO), New Zealand
**Home Institute Collaborators**: Prof. Sean Fitzsimons

**Visiting period:** May to August 2016

**Aim:** Compare airborne and ground-based radar data at the Southern McMurdo Ice Shelf (SMIS) to detect marine ice thickness and distribution

**Background:**
Ice shelves fringe about half of Antarctica's coastline (Drewry and others, 1982), where they buttress the flow of most outlet glaciers and ice streams (Pritchard and others, 2012). Marine ice forms below ice shelves from a supercooled mixture of sea and freshwater and is accreting in open basal weaknesses, such as rifts, crevasses and suture zones or as a massive layer below meteoric ice (Craven and others, 2009, Jansen and others, 2013, Tison and others, 1993). Due to the stabilizing effect of marine ice on ice shelves, its presence contributes to a decrease in Antarctic glacier discharge into the ocean and hence influences glacier and ice sheet mass balance (Depoorter and others, 2013). Improving the knowledge of marine ice distribution hence provides valuable input to numerical simulations of the behaviour of Antarctic glaciers and their contribution to sea level in a changing climate. Recently collected ground-based ice penetrating radar (IPR) data measured at the Southern McMurdo Ice Shelf (SMIS) showed that some marine ice properties can be detected with IPR despite its higher salinity and thus permittivity in comparison to meteoric ice. Airborne IPR lines were flown to match the ground-based data and are compared in detail to the ground-based data to determine instrument detection limits. Assessing the ability of airborne radar to detect marine ice will enable more comprehensive mapping of marine ice in Antarctica. Mapping the horizontal and vertical distribution of marine ice at SMIS will help to decipher its formation process.

**Methods/processing**
Surface radar data were collected with a pulseEKKo Pro radar at frequencies of 50 MHz using a 800W power transmitter (Fitzsimons and others, 2012) by the UO in 2010/2011. Airborne radar data were collected by UTIG in November 2014 along several flightiness overlapping with the ground-based data with the UTIG High Capability Airborne Radar Sounder (HiCARS) centered at 60 MHz powered by a 8000W transmitter (Peters and others, 2005) together with a 2.5 MHz system powered by a 2000W transmitter.

- Ground and airborne IPR data were geolocated trace by trace (1m spacing) and matched to facilitate comparison.
- The raw radar data were dewowed, enveloped or focused to remove noise using appropriate software and scripts (Pulse Ekko Pro and processing scripts written at UTIG).
- All radar data were picked for prominent layers such as the ice shelf base and marine ice – meteoric ice transition using UTIG developed software.
- Airborne surface reflectors were investigated using the radar statistical reconnaissance (RSR) technique to get density and surface roughness over SMIS. This was compared to *in situ* measurements of ice composition and surface accumulation and ablation (as determined by a surface mass balance stake survey).
- Basal reflectors and marine ice-meteoric ice interface reflectors were investigated for their reflectivity and RSR to determine how the reflector properties change dependent on interface properties.
- The ice shelf thickness was calculated along the radar lines accounting for the ice's changing velocity dependent on its density change with depth. Ground-based and airborne results were compared.

- Laser altimetry data was geolocated and processed for airplane rolling. This data together with ice shelf thickness allows for hydrostatic calculations to determine the marine ice thickness below SMIS.

**Preliminary results**

- Marine ice internal and interface layers can be detected with the ground penetrating IPR up to a thickness of around 50m, after that, the signal becomes lost. The airborne radar reflector signal is much weaker and the standard processing of the data needs to be minimized to allow for detection of internal layers.
- Ice shelf thicknesses calculated by processing airborne and ground-based IPR data are matching.
- Marine ice internal radar reflectors and changes in marine ice composition do not line up consistently. This may indicate that the sampled ice cores are too short and that longer ice cores would need to be analysed.
- Density and roughness as calculated by RSR over SMIS match *in situ* field observations of surface accumulation and marine ice distribution (through ice samples).

**Future/ additional work**

- Gravity and magnetics data that were collected along the airborne flight lines (e.g. Greenbaum et al., 2015) will be matched/validated with sea floor depth as collected by a seismic survey over SMIS (Johnson et al., 2008). Mapping the thickness of the ice shelf cavity using bathymetry together with the mapped marine ice spatial distribution and thickness will help to accurately determine the marine ice formation process, which depends on the ocean cavity below.
- Due to changes of staff in April 2016 at UTIG, no dielectric measurements on marine ice samples were conducted during my visit. However, my existing information on marine ice sample composition was informative enough for the comparison exercise of airborne and groundbased IPR data. With additional time for the radar data, we extracted even more detailed ice properties from radar data than anticipated, such as surface density and roughness, which could be compared to *in situ* observations of ice shelf surface accumulation and ablation (AGU abstract submitted). Nonetheless, discussions and negotiations toward a high profile proposal on marine ice dielectric experiments (with high laboratory costs) were started. These experiments will quantify the exact radar detection limits for specific marine ice properties. This will also benefit the planetary research community since marine ice is used as an analogue to Europa's ice shell.

**Candidate and Host Institute benefits**

- *Candidate benefits:* The candidate received state of the art training in radar processing, familiarized herself with new specialist software and got access to a unique and comprehensive airborne IPR dataset over SMIS.
- *Host institute benefits:* The collaborators at UTIG developed an understanding of the SMIS field area and marine ice distribution through the ground based IPR data and ice composition samples. Thus, it was possible to assess the airborne instrument's limitations for observing the presence of marine ice and its properties.

**Conference presentations and publications**

- AGU conference presentation (abstract submitted August 2016): Grima, C., E. J. Lopez Garcia, ***I. Koch***, J. S. Greenbaum, K. M. Soderlund, D. D. Blankenship, D. A. Young and S. Fitzsimons: 'Surface Density, Roughness, and Brine Infiltration Observed with Airborne Radar Statistical Reconnaissance at The McMurdo Ice Shelf, Antarctica' – a subsequent publication focusing on SMIS surface density and roughness will be submitted to Geophysical Research Letters.
- First-author presentation of SMIS marine ice distribution and detection with IPR planned for EGU or IGS 2017.

- Scientific publication on SMIS marine ice distribution and detection with IPR validated through the composition of ice samples to be submitted to the Journal of Geophysical Research or Geophysical Research Letters in 2017.

**Budget** (total: US$ 14000 plus US$ 500 for conference attendance)
- Lodging and living allowance for 90 days: US$ 9000
- Travel insurance and internal/local transport: US$ 1800
- Return flight to Austin: US$ 3200

I would like to use the funds I was given to attend the SCAR symposium (US$ 500) toward presenting results from this study at a different international conference when the data analysis is completed (e.g. IGS in Wellington in 2017 or EGU 2017 – either conference offers fitting thematic sessions) or toward a first-author scientific publication.

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