SCAR Fellowship Report 2015/2016

Participant:

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Project title:

Analysis of Antarctic subglacial hydrological development in Aurora Basin using aerogeophysical data and numerical modeling.

Host:

Dr. Jason Roberts

Australian Antarctic Division, Hobart, Australia

Duration:

May 14th 2016-June 27th 2016

Background:

In a warming climate it is vital to understand controls on the stability and mass balance of the Antarctic ice sheets. Water at the base of the ice sheets directly controls ice dynamics and the discovery of hundreds of subglacial lakes storing vast quantities of water raises questions about the impact of filling and drainage of these reservoirs for future ice mass drawdown (Wright and Siegert, 2012).

In the Aurora Subglacial Basin, located in Wilkes Land of East Antarctica, little is known about the role of basal water in ice dynamics and how future variability in these systems could impact the mass balance of this region of the ice sheet. It has recently been found that Totten glacier, which drains Aurora Subglacial Basin, is thinning at an alarming and unprecedented rate, likely driven by oceanic basal melting (Greenbaum et al, 2015). The role of subglacial hydrology in both modulating the flow of ice and in delivering water into the ocean cavity underneath the outer portions of the glacier is unclear. These processes and their impact on sub-ice shelf circulation and associated melt/refreeze is an area of research vital for future prediction of Antarctic ice shelf stability and ice sheet mass balance.

Outcomes of fellowship:

With minimal direct access to the bed in the Antarctic, an ideal method for analyzing change in the subglacial system is to use numerical models. During my postdoctoral fellowship at NASA Goddard Space Flight Center, I adapted a state-of-the-art subglacial hydrology model, the Glacier Drainage System Model (GlaDS; Werder et al, 2013), for application to Antarctic subglacial lakes. I have previously successfully applied this model to Recovery Ice Stream (Dow et al., 2016, Dow et al., in prep) and it was therefore the ideal model to apply to Aurora Subglacial Basin. Subglacial hydrology models are limited by the quality of data that can be used as inputs and boundary conditions, such as the basal topography and the rate of water production at the bed. In the Antarctic, both the topography and melt rates are not well known, although aerogeophysical surveys such as those run by the International Collaborative Exploration of the Cryosphere through Aerogeophysical Profiling (ICECAP) project, are greatly enhancing our knowledge of basal conditions.

During this fellowship, I aimed to establish the role of basal hydrology in the dynamics of Aurora Subglacial Basin while taking account of unknowns in basal melt rate and topography. To achieve this, I ran GlaDS with multiple configurations. I used two topographies 1) Bedmap2 (Fretwell et al., 2013), adapted by Dr. Jason Roberts to include the ICECAP radar-based basal topography for this region, and 2) TELVIS, a mass conservation model developed by Dr. Roberts for basal topography outputs (Roberts et al., 2011), again utilizing radar data from ICECAP. I also applied two melt rates to the catchment. The first was a static catchment-wide melt rate, which is standard procedure for Antarctic models as little is known about the basal variability in water production. The second method was developed in collaboration with Dr. Felicity Graham from the Institute of Marine and Antarctic Science at the University of Tasmania. Dr. Graham applied the Ice Sheet System Model (ISSM) to the Aurora region and inverted for basal melt in steady-state conditions using a variety of geothermal heat inputs. I applied the resulting spatially-variable basal melt rates as inputs into GlaDS to establish the impact of this on ice dynamics in the Aurora Subglacial Basin. The two basal topographies and two basal melt rates were also applied with multiple basal conductivities as sensitivity tests of the model. To establish the most appropriate combination of model inputs, GlaDS outputs are compared with 'lake-like reflectors' at the bed identified from ICECAP data (Wright et al., 2012). The results of this work will be presented at the 2016 AGU Fall meeting and are currently being written into a manuscript.

During my time at the Australian Antarctic Division, I co-authored an article for the online magazine, The Conversation with Dr. Graham and Dr. Sue Cook. This article discussed subglacial lakes in the Antarctic and their varied characteristics and dynamics. To date, this article has been read by 38,000 people.

I also attended the FRISP conference held in Gothenburg Sweden in October 2016 to discuss the outcomes of this research and to solidify collaborations for continued work examining the Aurora Subglacial Basin with colleagues from the University of Tasmania who were also in attendance.

Future work:

During the SCAR Fellowship I initiated collaboration with multiple scientists at the Institute of Marine and Antarctic Science (IMAS) at the University of Tasmania, which is contributing to ongoing research. The outputs of the Aurora Subglacial Basin hydrology model will be used as inputs into an ocean model run by Dr. Dave Gwyther to establish the role of subglacial water for circulation in the Totten Ice Shelf cavity. I am also continuing to work with Dr. Felicity Graham to improve parameterizations of subglacial hydrology to be applied in ice sheet models.

Publications:

Dow, C.F., Roberts, J., Graham, F., Werder, M. Constraining Aurora Subglacial Basin hydrological processes using modelling and geophysical approaches. In preparation.

Dow C, Graham, F and Cook, S. What lies beneath Antarctic Ice: Lakes, Life and the Grandest of Canyons, *The Conversation*, The Conversation Media Group, Victoria, Australia, 18 July (2016) [Newspaper Article, non-refereed]

Presentations:

Dow, C.F., Werder, M., Graham, F., Roberts, J., Walker, R. and Nowicki, S. The impact of subglacial lakes on catchment-scale drainage dynamics in East Antarctica. AGU Fall Meeting, San Francisco. December 2016.

Financial statement:

Expenses	***Cost (US $)***
Flights	$2289
Accommodation	$2850
Living expenses	$1350
Airport transport	$157
FRISP conference (October 2016)	
Flights	$621
Registration	$412
Accommodation	$327
Airport transport	$77
	TOTAL: $8083

Amount awarded: $8060

Acknowledgements:

Many thanks to SCAR for this fellowship. In addition to providing me with an excellent opportunity to work with Dr. Jason Roberts at the Australian Antarctic Division and apply the model I use to other areas of the Antarctic, the time in Hobart allowed me to develop very valuable collaborations with a number of scientists.

I am very grateful to Dr. Jason Roberts for hosting me in Hobart and for assistance in getting the model up and running in addition to providing very useful inputs. Also thanks to Drs. Felicity Graham, Sue Cook and Dave Gwyther for inspiring science conversations and exciting collaborative opportunities. I am looking forward to continued work together in the future. I would also like to thank the University of Tasmania Ice Sheets Group as a whole who were extremely hospitable and welcoming, and provided a very productive and encouraging environment to work in.

References:

Dow, C.F., Werder, M.A., Nowicki, S., Walker, RT. (2016) Modeling Antarctic subglacial lake filling and drainage cycles. *The Cryosphere*, 10, 1381-1393, doi:10.5194/tc-10-1381-2016.

Fretwell, P., Pritchard, H. D., Vaughan, D. G., Bamber, J. L., Barrand, N. E., et al. (2013) Bedmap2: improved ice bed, surface and thickness datasets for Antarctica. *Cryosphere*. **7**, 375-393.

Greenbaum, J. S., Blankenship, D. D., Young, D. A., Richter, T. G., Roberts, J. L., Aitken, A. R. A. et al. (2015). Ocean access to a cavity beneath Totten Glacier in East Antarctica. *Nature Geoscience*, 8(4), 294-298.

Roberts, J. L., Warner, R. C., Young, D., Wright, A., van Ommen, T. D., Blankenship, D. D., Siegert, M., Young, N. W., Tabacco, I.E., Forieri, A., Passerini, A., Zirizzotti, A., and Frezzotti, M. (2011). Re-fined broad-scale sub-glacial morphology of Aurora Subglacial Basin, East Antarctica derived by an ice-dynamics-based interpolation scheme, *The Cryosphere*, 5, 551–560, doi:10.5194/tc-5-551-2011.

Werder, M. A., Hewitt, I. J., Schoof, C. G., & Flowers, G. E. (2013). Modeling channelized and distributed subglacial drainage in two dimensions. *Journal of Geophysical Research: Earth Surface*, *118*(4), 2140-2158.

Wright, A., & Siegert, M. (2012). A fourth inventory of Antarctic subglacial lakes. *Antarctic Science*, *24*(06), 659-664.

Wright, A. P., Young, D. A., Roberts, J. L., Schroeder, D. M., Bamber, J. L., Dowdeswell, J. A., et al. (2012). Evidence of a hydrological connection between the ice divide and ice sheet margin in the Aurora Subglacial Basin, East Antarctica. *Journal of Geophysical Research: Earth Surface*, 117, F01033.