Predicting potential anchor ice formation sites in coastal Antarctic Waters

Greg Leonard[1], Andrew Pauling[2], Sarah Mager[3] & Inga Smith[2]

[1]National School of Surveying
University of Otago, Dunedin, New Zealand
Email: greg.leonard@otago.ac.nz

[2]Department of Physics
University of Otago, Dunedin, New Zealand

[3]Department of Geography
University of Otago, Dunedin, New Zealand

Presented at SIRC NZ 2013 – GIS and Remote Sensing Research Conference
University of Otago, Dunedin, New Zealand
August 29th – 30th 2013

***Keywords and phrases*:** anchor ice, Antarctica, ice shelf, terrain model, coastal bathymetry, McMurdo Sound

1.0 INTRODUCTION

The term anchor ice (see Figure 1) describes clusters of ice attached to the beds of rivers, lakes and the sea. This ice is an important vector for the mobilization of bed sediments and also serves an ecological role as a food source, habitat and potentially fatal environment for biological communities. In Antarctica, ice shelves and their associated plumes of supercooled water are believed to be a main driver behind the formation of anchor ice due to a process commonly referred to as an "ice pump". Relatively warm, salty seawater contacts the basal plane of an ice shelf causing it to melt. The resultant melt water, which is more buoyant than the ambient water due to its relative freshness, rises along the base plane becoming potentially supercooled in the process due to the pressure dependency of its freezing point with depth. Such plumes have been demonstrated to significantly enhance the growth of landfast sea ice in waters adjacent to an ice shelf front as the plume is swept out from underneath an ice shelf due to underlying currents. Anchor ice growth may be initiated in those regions where plumes intersect the local seafloor.

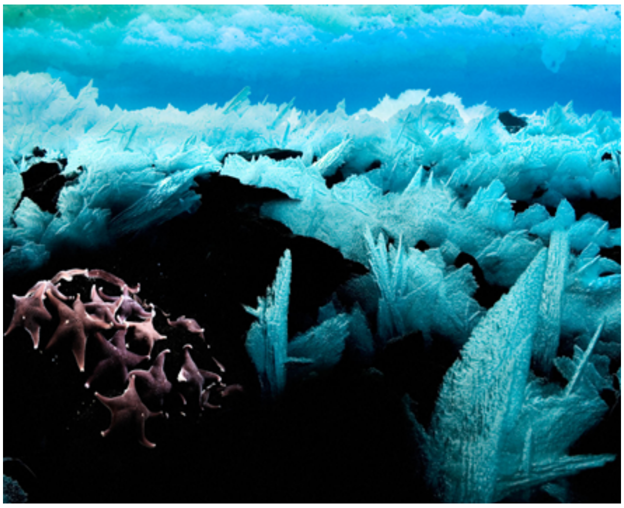

Figure 1: Anchor ice on the seabed in McMurdo Sound. Photo credit John B. Weller.

A recent review paper on anchor ice formation (Mager *et al*., 2013) identified the ice pump process as a significant driver of anchor ice formation in Antarctic coastal waters. One key observation from their work is that there have been no reports of anchor ice in Antarctic waters at depths greater than 30 m, even though an ice pump could theoretically initiate anchor ice growth at greater depths. It is not known how far beyond the edge of an ice shelf a supercooled plume may persist, although current work undertaken in McMurdo Sound indicates that this may be up to a maximum of around 250 km (Hughes, 2013). Information on where anchor ice is likely to form will be useful for Antarctic researchers investigating benthic ecosystems, sediment transport and sea ice / ice shelf interactions. In this study we aim to identify potential sites suitable for anchor ice formation around the Antarctic continent through the use of a 1st order geospatial model that is informed by the current understanding of anchor ice formation processes in Antarctica.

2.0 METHODS

Key inputs to the geospatial model are the Antarctic Digital Database (SCAR, 2012) and digital elevation models (DEMs) of Antarctic coastal waters and parameterizations of anchor ice formation processes. Pan-Antarctic DEMs include Bedmap2 (Fretwell *et al.*, 2013) and the International Bathymetric Chart for the Southern Ocean (IBCSO 1.0) (Arndt *et al.*, 2013), however, a recently undertaken comparison between Bedmap2 and IBCSO yielded elevation anomalies upwards of ± 2.4 km (See Figure 2). Thus a synthesis of pan-Antarctic and regional or local bathymetry products is necessary to produce the accuracy required to predict anchor ice formation sites as the depth of the seafloor is a critical factor in this endeavour. We make use of marine trackline bathymetry data and regional bathymetric data (where available) to validate and adjust, where necessary, larger scale bathymetry models. The marine trackline data from research vessels is readily available via data centres such as the National Geophysical Data Center (NGDC) while regional bathymetry data is available from national-body research institutes (e.g. GNS, Australian Antarctic Division, etc.).

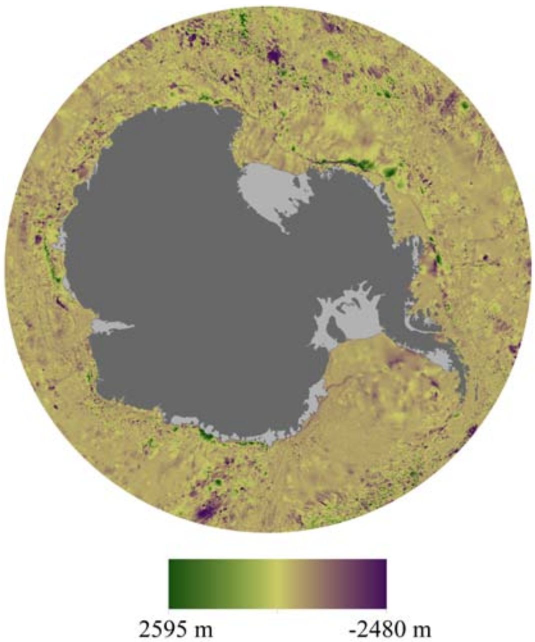

Figure 2: Comparison of Bedmap2 and IBCSO bathymetry. Pixel resolution is 500 m.

Once the trackline bathymetry data is sourced and collected, location and elevation data is extracted from the trackline bathymetry data using the open source software package MB-System and stored in an ESRI file geodatabase. In regions where there is sufficient density of tracklines and local bathymetry data, these will be combined to create ESRI Terrain models of the local seafloor. These terrains are then compared to gridded bathymetry data to determine potential erroneous data, and where there is sufficient data, a 3D surface of the coastal sea floor will be generated, following the method of Basu and Malhotra (2002). An example of a terrain model constructed from a synthesis of regional and pan-Antarctic bathymetry data for McMurdo Sound in shown in Figure 3. Ultimately this process will be replicated for suitable coastal regions across the entire Antarctic continent, although in this paper we are only presenting work undertaken in McMurdo Sound. Once the bathymetric data has been synthesised for a particular region, a 1st order geospatial model is constructed and used to locate intersections between ice shelf plumes and the local seafloor, and hence predict potential anchor ice formation sites. Model sensitivity will be examined by modifying key input parameters, such as plume depth and extent and degree of supercooling.

3.0 SUMMARY

This works represents the first steps towards predicting anchor ice formation sites along the entirety of the Antarctic coastline. It builds on work that has been undertaken over the past two summers at the University of Otago that included the review of current literature to determine the state of knowledge of anchor ice formation processes and the extent of anchor ice observations, the identification of likely formation processes for Antarctic anchor ice and the construction of a preliminary prediction model for McMurdo Sound. This work is expanded on here by refining the underlying bathymetry models and assessing model sensitivity to key input parameters. It is envisaged that the output from the modelling work will provide the basis of a future field-based study examining the physical and chemical characteristics of anchor ice.

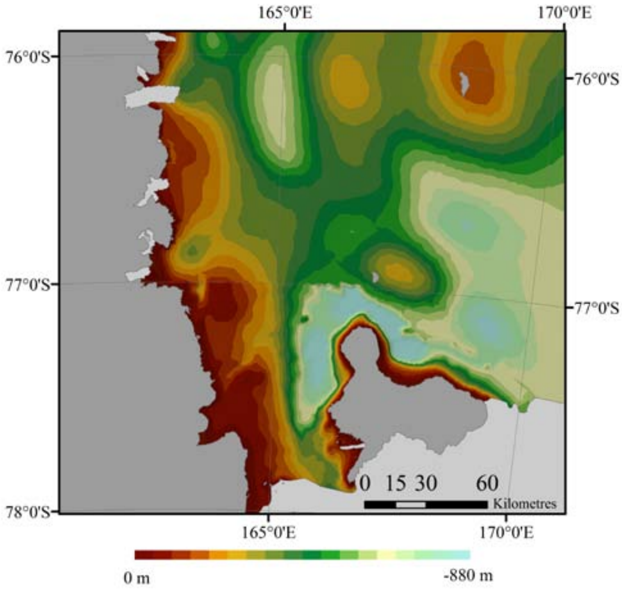

Figure 3: ESRI Terrain model of McMurdo Sound Antarctica shown in a Lambert Conformal Conic projection. GNS regional bathymetry is used for areas south of the 77th parallel, while Bedmap2 bathymetry is used for areas to the north of the 77th parallel.

REFERENCES

Arndt, J. E., H. W. Schenke, M. Jacobsson, F.O. Nitsche, G. Buys, B. Goleby, M. Rebesco, F. Bohoyo, J. Hong, J. Black, R. Greku, G. Udintsev, F. Barrios, W. Reynoso-Peralta, M. Taisei and R. Wigley (2013) The International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0 – A new bathymetric compilation covering circum-Antarctic waters. *Geophysical Research Letters*, doi 10.1002/grl.50413.

Basu, A. and Malhotra, S. (2002) Error detection of bathymetry data by visualization using GIS. *ICES Journal of Marine Science*, 59: 226 – 234.

Fretwell, P. and 59 others (2013) Bedmap2: Improved ice bed, surface and thickness datasets for Antarctica, *The Cryosphere*, 7, 375 – 393.

Hughes, K. (2013) Propagation of an ice shelf water plume beneath sea ice in McMurdo Sound, Antarctica, *MSc Thesis (submitted)*, University of Otago, New Zealand.

Mager, S. M., I. J. Smith, E. W. Kempema, B. J. Thomson and G. H. Leonard (2013) Anchor ice in polar oceans. *Progress in Physical Geography*, doi: 10.1177/0309133313479815.

SCAR (2012) Antarctic Digital Database, Version 6.0, http://www.add.scar.org/.