BRIEF COMMUNICATION: IMPACTS OF A DEVELOPING POLYNYA OFF COMMONWEALTH BAY, EAST ANTARCTICA, TRIGGERED BY GROUNDING OF ICEBERG B09B

Christopher J. Fogwill[1*], Erik van Sebille[2], Eva A. Cougnon[3,4,5], Chris S.M. Turney[1], Steve R. Rintoul[3,4,5], Benjamin K. Galton-Fenzi[4,6], Graeme F. Clark[1], E.M. Marzinelli[1], Eleanor B. Rainsley[7], Lionel Carter[8].

[1] Climate Change Research Centre, School of Biological, Earth and Environmental Sciences, UNSW Sydney, Australia

[2] Grantham Institute & Department of Physics, Imperial College London, United Kingdom

[3] Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, Tasmania 7001, Australia.

[4] Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Private Bag 80, Hobart, Tasmania 7001

[5] Commonwealth Scientific and Industrial Research Organisation, Ocean and Atmospheric Research, Hobart, Australia.

[6] Australian Antarctic Division, Kingston, Tasmania

[7] Wollongong Isotope Geochronology Laboratory, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, Australia.

[8] Antarctic Research Centre, Victoria University of Wellington, New Zealand

*Correspondence to c.fogwill@unsw.edu.au

Abstract. The dramatic calving of the Mertz Glacier Tongue in 2010, precipitated by the movement of iceberg B09B, reshaped the oceanographic regime across the Mertz Polynya and Commonwealth Bay, regions where high salinity shelf water (HSSW) – the precursor to Antarctic bottom water (AABW) – is formed. Here we compare post-calving observations with high-resolution ocean modelling, which suggest that this reconfiguration has driven the development of a new polynya off Commonwealth Bay, where HSSW production continues due to the grounding of B09B. Our findings demonstrate how local changes in icescape can impact formation of AABW, with implications for large-scale ocean circulation and climate.

1. Introduction

The events triggered by the movement of the 97km long iceberg B09B adjacent to the Mertz Glacier Tongue (MGT) in 2010 precipitated a significant iceberg calving event that was captured in real time from satellite data and shipboard observations (Shadwick et al., 2013). Prior to the calving event, Commonwealth Bay – the site of Sir Douglas Mawson's Australasian Antarctic Expedition (AAE) of 1911–1914 – was usually free of sea ice, owing to the presence of an extensive coastal polynya maintained by strong off-shore katabatic winds sustained by the local ice-sheet topography and the presence of the Mertz Polynya to the east. Historically, newly-formed sea ice has been rapidly transported offshore by these winds; for example, during the original AAE of 1911-1914, the sea ice in Commonwealth Bay was stable enough to walk on for only two days each year (Mawson, 1940). In December 2010, however, the grounding of iceberg B09B in Commonwealth Bay in 2010 changed the local icescape considerably (Shadwick et al., 2013; Lacarra et al., 2014) (Figure 1A). The presence of the grounded iceberg B09B since 2010 has blocked the off-shore transport of sea ice, leading to the build-up of year-round fast-ice up to 3m thick landward of the iceberg (Clark et al., 2015). This transition from an area that was often ice-free to one of continuous fast-ice cover has created a natural experiment into the impacts of fast-ice change on both local biota (Clark et al., 2015) and ocean circulation (Shadwick et al., 2013; Lacarra et al., 2014). The latter is particularly important given the Adélie-George V Land region is a key region of formation of Antarctic bottom water (AABW; a generic term that encompasses the variable nature of such bottom waters (Orsi et al., 1999; van Wijk and Rintoul, 2014; Nihashi and Ohshima, 2015)). Prior to the calving of the Mertz Glacier, both the the Mertz and Commonwealth Bay polynyas were important sources of high salinity shelf water (HSSW) and dense shelf water (DSW) formation, which are precursors to AABW. As AABW supplies the lower limb of the global thermohaline circulation system (Orsi et al., 1999), changes in the properties or rate of formation of AABW in response to the local icescape can influence the continental shelf sea circulation (Cougnon, 2016), with widespread consequences on deep ocean circulation and ventilation (Kusahara et al., 2011; Shadwick et al., 2013).

The loss of the 78 km-long Mertz Glacier Tongue in 2010, which had previously reduced westward flow of ice into the Mertz Polynya and Commonwealth Bay, is estimated to have caused a marked reduction of sea-ice formation regionally (Tamura et al., 2012). Furthermore, model studies suggest that this has led to a reduction in HSSW formation in the area (Kusahara et al., 2011), a hypothesis supported by *in situ* observations in 2011/2012 (Shadwick et al., 2013; Lacarra et al., 2014). Together, these data indicate an abrupt reduction in the salinity and density of shelf water and an increase in carbon uptake in the region of the Mertz Polynya when compared to pre-calving levels. Palaeoceanographic studies suggest that the impacts of MGT calving on AABW formation may be a cyclical process, occurring on centennial timescales (Campagne et al., 2015).

Given that the majority of AABW is formed at a number of principal sites around Antarctica (Orsi et al., 1999: Cougnon 2016) – including the Weddell Sea, the Ross Sea, Amery-Shackleton ice shelf, Cape Darnley, Vincennes Bay and Adélie-George V Land – any major long-term circulation change in these regions could have a significant impact on the global climate system. At present the long-term stability of AABW formation is not fully understood, and it is possible that the rates of AABW production from regional areas are highly variable both temporally and spatially. Therefore, studying the impacts of natural perturbations such as the grounding of B09B can provide insights into the sensitivity of AABW formation to past and future changes in regional icescape (Broecker et al., 1998; Marsland et al., 2004; Cougnon et al., 2013).

Here we report new data that provides a snapshot of change in the region of the Mertz Polynya and Commonwealth Bay from *in situ* oceanographic observations from December 2013, the austral summer (Figure 1). We compare these results with high-resolution regional ocean model simulations that examine pre- and post-calving ocean dynamics, particularly changes in velocity and advection of water masses between the Mertz Polynya and Commonwealth Bay for scenarios pre- and post-grounding of B09B in 2010.

2. *In situ* observations and model simulations

2.1 *In situ* observations

We report observations of changes in ocean water properties recorded during December 2013 on the Australasian Antarctic Expedition 2013-2014 (AAE 2013-2014) from the *MV Akademik Shokalskiy*. A research programme was designed to examine the changes in the region since the Mertz Glacier calving event in 2010, building upon observations from previous research expeditions in the region (Shadwick et al., 2013; Lacarra et al., 2014). To compare the current oceanographic conditions in the region with previous measurements, expendable conductivity temperature and depth probes (XCTDs; model XCTD-1, Tsurumi-Seiki Co.) were deployed, which were assessed against a Seabird-SBE37SM microcat CTD calibrated for cold water conditions (see SOM Figure S1). A TSK TS-MK-21 expendable XCTD system was used to gather oceanographic data, which was recorded on a laptop computer. Given the marked expansion of fast-ice in Commonwealth Bay, in some locations XCTDs and the microcat were deployed through the fast-ice as well as in open water from the vessel. Although some deployments were opportunistic, many were repeat casts of previous stations in Commonwealth Bay and in the Mertz Polynya to allow direct comparison with studies taken during past austral summers (Figure 1).

2.2 Modelled simulations

To gain an increased understanding of the regional oceanographic changes triggered by the events that began in 2010, high-resolution regional ocean model simulations were undertaken using a modified Rutgers version of the Regional Ocean Modeling System (ROMS) (Shchepetkin and McWilliams, 2005), with a model setup following Cougnon (2016; see SOM for full model description and set up). The model includes ocean/ice-shelf thermodynamics and frazil ice thermodynamics, but does not include sea-ice model/ocean coupling. Without a dynamic sea-ice model, the fine-scale polynya activity is resolved by forcing the surface of the model with monthly heat and salt fluxes from Tamura *et al*. (2016) data set that is based on sea-ice concentration estimated with the Tamura *et al*. (2007) algorithm. This algorithm estimates thin ice thickness using Special Sensor Microwave Imager (SSM/I) observations and the European Centre for Medium-Range Weather Forecast Re-Analysis data (ERA-Interim). In summer the data set is supplemented with heat and salt fluxes using monthly climatology from ERA-interim. The model simulations are forced at the surface with data from the year 2009 (pre-calving) and 2012 (post-calving), providing general information on the ocean circulation for stable ice geometries that includes melt water from the B09B and other fast-ice and icebergs/ice shelves present in the domain. The results from these simulations are not restricted to the year chosen for the forcing, and can be compared with other years of similar salt and heat flux intensity both pre- and post-calving (see SOM for discussion). The same lateral boundary forcing is used in both pre- and post-calving simulations. Lateral boundary fields, including salinity, horizontal velocities and potential temperature, were relaxed to a climatology calculated from monthly fields estimated from the circulation and climate of the ocean, Phase II synthesis (ECCO2) for the period 1992-2013 (Wunsch, 2009).

3 Results

3.1 Comparison with past data

The XCTD results from December 2013 are divided into three geographic areas to allow direct comparison with data from previous cruises from the same season (Figure 1 and SOM). Salinity and temperature data from the austral summer 2013/14 from northwest of Commonwealth Bay ('Commonwealth Bay NW'), northeast ('Mertz NE') and southwest ('Mertz SW') of the MGT are compared to previous years in Figure 1B, C and D respectively. As salinities and water density vary both spatially and seasonally across the region we can only compare our data to that collected in similar seasons and locations (Figure 1).

Calving of the Mertz Glacier released a large volume of sea ice from the immediate east of the MGT. Subsequent melting of the sea ice produced a significant input of fresh water and rapid freshening of the upper ocean post-calving (Shadwick et al., 2013), as seen in Figures 1C, D. Our observations suggest a partial recovery of upper ocean salinity by 2013 in the Mertz NE and Mertz SW regions. The 2013 measurements do not extend to sufficient depth to sample the HSSW layer. However, the reduction in the amount of buoyant fresh water in the upper water column may pre-condition these regions for a resumption or strengthening of HSSW formation in future years, if sufficient formation of sea ice and subsequent brine rejection occurs. Prior to the grounding of B09B in its present position, intrusions of relatively warm modified Circumpolar Deep Water were observed in the Mertz NE region (Figure 1F). The water column in 2013 is also colder (~0.8˚C), perhaps because the iceberg is blocking inflow of the warmer water from the east.

Data from the polynya west of B09B (Commonwealth Bay NW) shows evidence of a shift in water properties following the grounding of B09B in its position during December 2013 (Figure 1B, E). Prior to the grounding, the water column was stratified, with relatively warm and fresh water overlying a colder, saltier layer. Following the grounding of B09B, the entire water column below 100dbar became saltier, colder and evidently more well-mixed. These observations suggest deep convection and HSSW formation now occurs in the polynya west of B09B, in a region where historically no HSSW was formed. The deep salinity values observed in the polynya west of B09B in 2013 (34.60‰ to 34.61‰) were higher than the salinities of 34.50‰ to 34.55‰ observed prior to calving, although still substantially less than the HSSW formed in the Mertz and Commonwealth Bay polynyas pre-calving.

3.2 Model simulation results

The numerical simulations pre- and post-calving indicate a change in oceanographic conditions in the area of the B09B iceberg, demonstrating the development of a polynya area in the lee of B09B post-calving. The modelled sea-ice production (Tamura et al 2016) within the Mertz Glacier polynya decreases and is restricted to an area closer to the coast. On the other hand, sea-ice production in the lee of the B09B iceberg post-calving is shown to increase markedly (Figures 2A and B).

The modelled ocean circulation for December shows that pre-calving, a westward coastal current carried water masses from the Mertz polynya and Commonwealth Bay areas towards the Commonwealth Bay NW XCTD positions (red squares on Figures 2A and B), forming a stratified water column with warm and fresh surface water (Figure 2C). The cold and salty water mass simulated pre-calving at the NW Commonwealth Bay XCTD positions is advected from the Mertz polynya and

Commonwealth Bay post-calving. Modelled water column stratification is stronger in winter when there is sea-ice production. The model simulates a relatively warm layer at around 150 m depth (-1.18 ˚C) in July pre calving (Figure 2D). From 250 m to the ocean floor there is a cold (-1.92 ˚C) and salty (34.67) water mass that originates from the advection of HSSW from the Mertz polynya and Commonwealth Bay.

Post calving, the coastal current is blocked by the B09B iceberg, associated with a decrease in sea ice production within the Mertz polynya; little HSSW is advected into the area of the Commonwealth Bay NW XCTDs. The model average for December shows a stratified water column in summer, due to the advection from the north of a relatively warm water mass in summer. However, in winter the water column post calving at the Commonwealth Bay NW XCTDs is entirely homogeneous in potential temperature (-1.90 ˚C) and salinity (34.54), illustrating an active polynya that locally produces HSSW capable of being convected to the sea floor. The model does not simulate an increase in salinity post-calving, but the seasonality illustrates the potential of a polynya developing in the lee of the B09B iceberg to locally form HSSW dense enough to sink to the sea floor, as inferred from the trends in the summer observations. It should be noted that our model simulations do not show the current evolution of the impact of the calving, but rather simulate the ocean conditions for two stable ice geometries, before and after the Mertz calving, thus can not be directly inter-compared to our XCTD data. However, the trends indicated from our regional model simulations provide valuable insights into mechanisms driving the circulation changes triggered as a response to the grounding of B09B off Commonwealth Bay.

4 Discussion

In combination the *in situ* XCTD measurements, satellite observations and high-resolution regional ocean modelling across the Mertz Polynya and Commonwealth Bay provide valuable insights into ocean dynamics post-Mertz calving in this region critical to HSSW production. Whilst the implications for shifting focus of HSSW on regional AABW formation are currently unquantified, the changes recorded locally, particularly the blocking effect that B09B has on the coastal current since 2010, demonstrate that this region is still undergoing marked and dramatic oceanographic changes that have important implications (Shadwick *et al*., 2013; Clark et al., 2015).

4.1 A developing polynya

Combined, our XCTD data and the high-resolution model simulations suggest that the regional reconfiguration of the Mertz Polynya and Commonwealth Bay due to B09B has led to a shift in the focus of HSSW production (Figure 1), and importantly, enhanced sea-ice production in the lee of B09B since its grounding in Commonwealth Bay in 2010 (Figure 2). Data from Commonwealth Bay NW in particular suggests that a new polynya has developed west of B09B, where today HSSW is formed outside the previously well established foci of regional HSSW production in the former Mertz or Commonwealth Bay polynyas (Lacarra et al., 2014). The effect this change of location will have on regional ocean circulation is currently unknown, and much of the impact depends on the changes occurring deep in Commonwealth Bay itself under the perennial fast-ice that has formed across the bay due to the grounding of B09B (Clark et al., 2015; Lacarra et al., 2014; Cougnon, 2016).

Whilst the observations we present cannot account for seasonal variability (Lacarra et al., 2014), which can only be fully reconciled by the recovery and analysis of the *in situ* CTD arrays deployed in the region, our data and model analysis suggest that water mass characteristics have been affected markedly in the area off Commonwealth Bay. Regardless, our analysis shows the grounding of B09B off Commonwealth Bay in 2010 has apparently led to the development of a new polynya to its leeward side that is capable of producing HSSW outside the Mertz Polynya or the former Commonwealth Bay Polynya.

5. Conclusions

Observations and model simulations provide evidence that changes in the regional icescape have led to a shift in the location of polynyas and HSSW formation on the Adélie Land continental shelf. While the salinity of HSSW produced in the B09B polynya does not reach the high values observed in the Mertz and Commonwealth Bay polynyas pre-calving of the MGT, HSSW formed in the new polynya compensates in part for the reduction in dense water production by these now much weaker polynyas.

Before the Mertz Glacier calving event, dense shelf water production from the Adélie shelf supplied 15-25% of the global volume of AABW (Rintoul, 1998). Several studies have documented the decrease in activity of the Mertz and Commonwealth Bay polynyas, and reduction in salinity and density of HSSW, following the calving event (Shadwick et al., 2013; Tamura et al., 2012). Our modelling shows marked changes in sea ice production post-MGT calving, with reductions in both the Mertz Polynya and in Commonwealth Bay. Importantly, our model simulations suggests production of HSSW, dense enough to sink to the sea floor and eventually contribute to DSW formation in the lee of B09B (Figure 2). This study further enhances our understanding of the sensitivity of HSSW and AABW formation to changes in the local icescape, and illustrates how movement of large icebergs can alter regional ocean circulation and air-sea interaction patterns, producing new polynyas and hence new regions of dense water formation.

AABW formation is highly sensitive to changes in the ocean-ice domain and forms a critical component of global thermohaline circulation. Studies of the response of the ocean and cryosphere to events like the calving of the Mertz Glacier and grounding of B09B in Commonwealth Bay provide insight into the consequences of natural and anthropogenic-driven changes. The observed formation of AABW is limited to a few locations around Antarctica, where conditions transform buoyant surface waters to water of sufficient density to sink to the sea floor, maintaining the deep ocean stratification, contributing to large-scale heat and salt budgets, and ventilating the abyss (Orsi et al., 1999). Our work underscores the remarkable sensitivity of this global phenomenon to local changes in the cryosphere.

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7. References

Broecker, W., Peacock, S., Walker, S., Weiss, R., Fahrbach, E., Schröder, M., Mikolajewicz, U., Heinze, C., Key, R., and Peng, T.: How much deep water is formed in the Southern Ocean?, Journal of Geophysical Research, 103, 15833-15843, 1998.

Campagne, P., Crosta, X., Houssais, M. N., Swingedouw, D., Schmidt, S., Martin, A., Devred, E., Capo, S., Marieu, V., Closset, I., and Massé, G.: Glacial ice and atmospheric forcing on the Mertz Glacier Polynya over the past 250 years, Nat Commun, 6, 10.1038/ncomms7642, 2015.

Clark, G., Marzinelli, E., Fogwill, C. J., Turney, C. S. M., and Johnston, E.: Effects of sea-ice cover on marine benthic communities: a natural experiment in Commonwealth Bay, East Antarctica, Polar Biol, 1-10, 10.1007/s00300-015-1688-x, 2015.

Cougnon, E. A., Galton-Fenzi, B. K., Meijers, A. J. S., and Legrésy, B.: Modeling interannual dense shelf water export in the region of the Mertz Glacier Tongue (1992–2007), Journal of Geophysical Research: Oceans, 118, 5858-5872, 10.1002/2013JC008790, 2013.

Cougnon, E. A., Modelling the sensitivity of dense shelf water formation in the Mertz Glacier region, East Antarctica" June 2016, Unpublished PhD thesis. 210 pages, University of Tasmania

Kusahara, K., Hasumi, H., and Williams, G. D.: Impact of the Mertz Glacier Tongue calving on dense water formation and export, Nat Commun, 2, 159, 2011.

Lacarra, M., Houssais, M.-N., Herbaut, C., Sultan, E., and Beauverger, M.: Dense shelf water production in the Adélie Depression, East Antarctica, 2004–2012: Impact of the Mertz Glacier calving, Journal of Geophysical Research: Oceans, 119, 5203-5220, 10.1002/2013jc009124, 2014.

Marsland, S. J., Bindoff, N. L., Williams, G. D., and Budd, W. F.: Modeling water mass formation in the Mertz Glacier Polynya and Adélie Depression, East Antarctica, Journal of Geophysical Research: Oceans, 109, C11003, 10.1029/2004JC002441, 2004.

Mawson, D.: Oceanography. Part 4. Hydrological Observations, Sydney, 24, 1940.

McCartney, M. S., & Donohue, K. A. (2007). A deep cyclonic gyre in the Australian–Antarctic Basin. *Progress in Oceanography*, *75*(4), 675-750.

Nihashi, S., and Ohshima, K. I.: Circumpolar Mapping of Antarctic Coastal Polynyas and Landfast Sea Ice: Relationship and Variability, Journal of Climate, 28, 3650-3670, 10.1175/JCLI-D-14-00369.1, 2015.

Orsi, A. H., Johnston, G. C., and Biullister, J. L.: Circulation, mixing, and production of Antarctic Bottom Water, Progress in Oceanography, 43, 55-109, 1999.

Rintoul, S.: On the origin and influence of Ade´lie Land Bottom Water, in Ocean, Ice and Atmosphere: Interactions at the Antarctic Continental Margin, Antarct. Res. Ser., vol. 75, edited by S. S. Jacobs and R. F. Weiss, pp. 151–172, AGU, Washington, D. C., 1998.

Shadwick, E. H., Rintoul, S. R., Tilbrook, B., Williams, G. D., Young, N., Fraser, A. D., Marchant, H., Smith, J., and Tamura, T.: Glacier Tongue calving reduced dense water formation and enhanced carbon uptake, Geophysical Research Letters, 40, 904-909, 10.1002/grl.50178, 2013.

Shchepetkin, A. F., and McWilliams, J. C.: The regional oceanic modeling system (ROMS): a split-explicit, free-surface, topography-following-coordinate oceanic model, Ocean Modelling, 9, 347-404, http://dx.doi.org/10.1016/j.ocemod.2004.08.002, 2005.

Tamura, T., Ohshima, K. I., Nihashi, S., and Hasumi, H.: Estimation of Surface Heat/Salt Fluxes Associated with Sea Ice Growth/Melt in the Southern Ocean, SOLA, 7, 17-20, 10.2151/sola.2011-005, 2011.

Tamura, T., Williams, G. D., Fraser, A. D., and Ohshima, K. I.: Potential regime shift in decreased sea ice production after the Mertz Glacier calving, Nat Commun, 3, 826, http://www.nature.com/ncomms/journal/v3/n5/suppinfo/ncomms1820_S1.html, 2012.

Tamura, T. Ohshima, K. I. Fraser, A. D. Williams, G. D. Sea ice production variability in Antarctic coastal polynyas. Journal of Geophysical Research: Oceans, 2016. ISSN 21699275. doi: 10.1002/2015JC011537.

van Wijk, E. M., and Rintoul, S. R.: Freshening drives contraction of Antarctic Bottom Water in the Australian Antarctic Basin, Geophysical Research Letters, 41, 2013GL058921, 10.1002/2013gl058921, 2014.

Wunsch, C., Heimbach, P., Ponte, R., Fukumori, I., and the ECCO-GODAE Consortium members. : The global general circulation of the ocean estimated by the ECCO Consortium. , Oceanography., June, 2009.

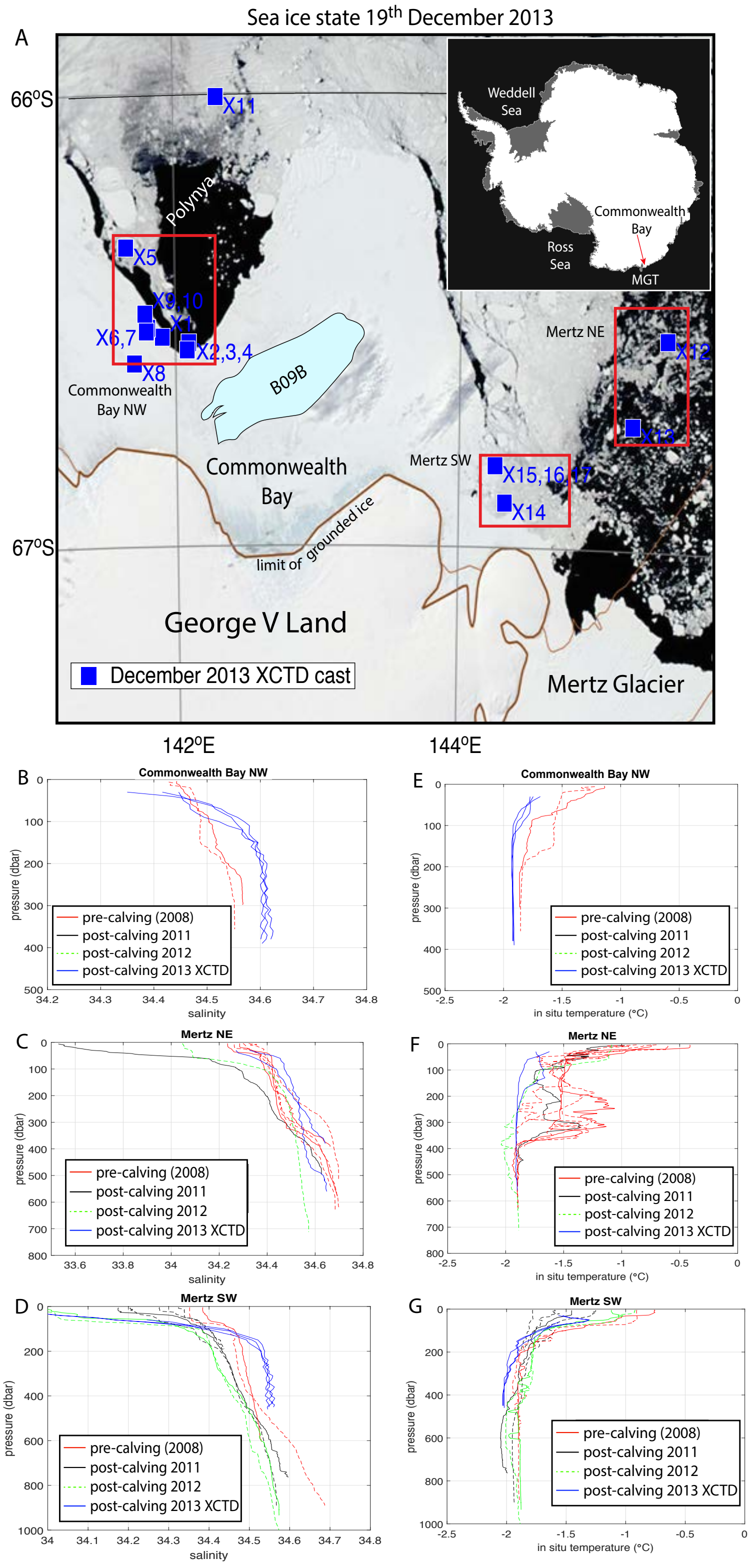
A
Sea ice state 19th December 2013
66°S
67°S
142°E
144°E
X11
Polynya
X5
X9,10
X1
X6,7
X2,3,4
X8
Commonwealth Bay NW
B09B
Commonwealth Bay
limit of grounded ice
George V Land
December 2013 XCTD cast
Mertz NE
X12
X13
Mertz SW
X15,16,17
X14
Mertz Glacier
Weddell Sea
Commonwealth Bay
Ross Sea
MGT
B
Commonwealth Bay NW
pressure (dbar)
salinity
pre-calving (2008)
post-calving 2011
post-calving 2012
post-calving 2013 XCTD
E
Commonwealth Bay NW
in situ temperature (°C)
C
Mertz NE
F
Mertz NE
D
Mertz SW
G
Mertz SW

Figure 1. A. Visible MODIS image of the Commonwealth Bay and Mertz Glacier region of Adélie Land, Antarctica on the 19th of December 2013 (credit Dr Jan Lieser: source NASA WORLDVIEW), with the sites of the December 2013 XCTD casts. The outline of the grounded B09B iceberg is indicated, with a map of the Antarctic Continent inset. Comparison between salinity from XCTD casts in 2013 (blue) and CTD profiles from previous years from 2012 (green), 2011 (black) and 2008 (pre-calving; red) B. Commonwealth Bay NW, C. NE Mertz and D. SW Mertz. Comparison between temperature from XCTD (Blue) casts in 2013 and CTD profiles from previous years 2012 (green), 2011 (black) and 2008 (pre-calving; red) in E. Commonwealth Bay NW, F. NE Mertz and G. SW Mertz (See SOM Figure S2 for details of specific sites of historic data).

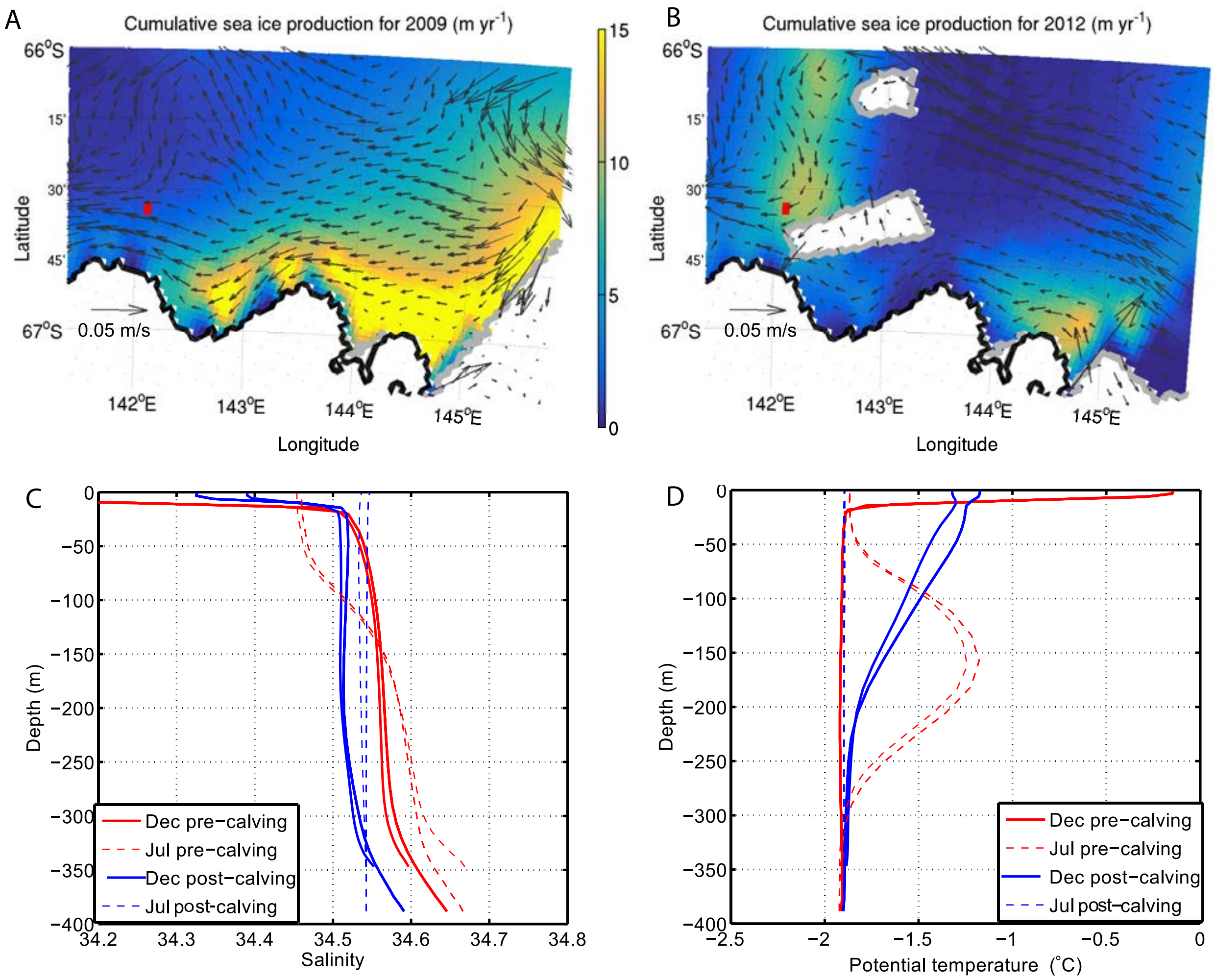

Figure 2. Upper panels: Cumulative sea ice production (m/yr) for the two years of forcing for A pre- (2009) and B. post- (2012) calving simulations, overlaid with the vertically integrated horizontal velocity (m/s) in December, from the model climatology (black vectors). Red squares mark the Commonwealth Bay NW XCTD sites used in Figure 1B and E, and the simplified outline of B09B in the model domain can be seen in B. Lower panels: salinity (C) and potential temperature (D) for the the XCTD stations in Commonwealth Bay NW, pre (red) and post calving (blue) simulations, averaged for December (solid line) and July (dashed line).