Sustained basal mass loss after the 2010 calving event of the Mertz Glacier

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[4]Australian Antarctic Division

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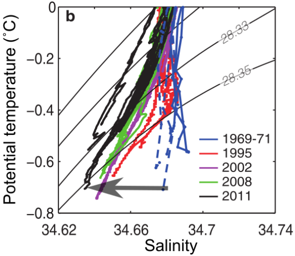
Motivations

AABW variability

- Antarctic Bottom Water (AABW) freshening and contracting *[e.g.: Rintoul 2007; Purkey and Johnson 2012; Aoki et al. 2013; van Wijk and Rintoul 2014]*



van Wijk and Rintoul, 2014 (GRL)

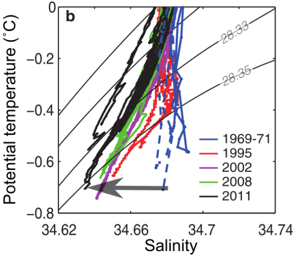
Motivations

AABW variability

- Antarctic Bottom Water (AABW) freshening and contracting *[e.g.: Rintoul 2007; Purkey and Johnson 2012; Aoki et al. 2013; van Wijk and Rintoul 2014]*

Possible causes:

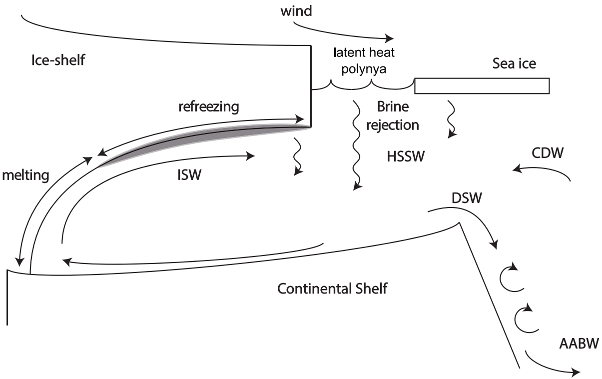
- **freshening of the shelf water**
- reduction in formation rate
- change of bottom water properties



van Wijk and Rintoul, 2014 (GRL)

How is AABW formed and where?

Atmospheric cooling, brine rejection and interaction with Antarctic ice shelves



Adapted from Galton-Fenzi et al. 2012 (JGR)

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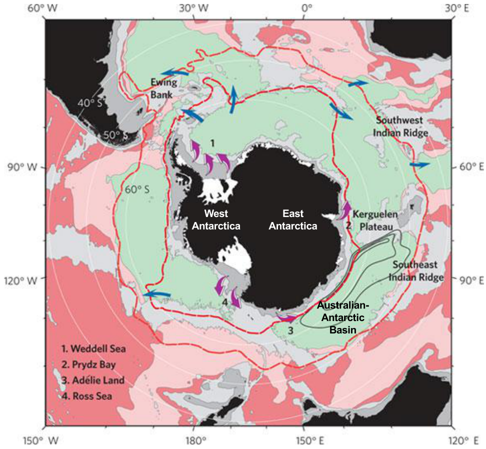
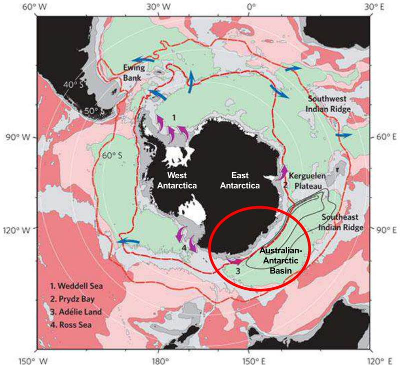


Orsi 2010 (Nat. Geo.)

- Weddell Sea
- Adélie Land
- Ross Sea
- Cape Darnley

Australian-Antarctic Basin

- high rate of sea ice production due to intense latent heat polynya
- high export of Dense Shelf Water (DSW)
- contributes to Antarctic Bottom Water formation (AABW)



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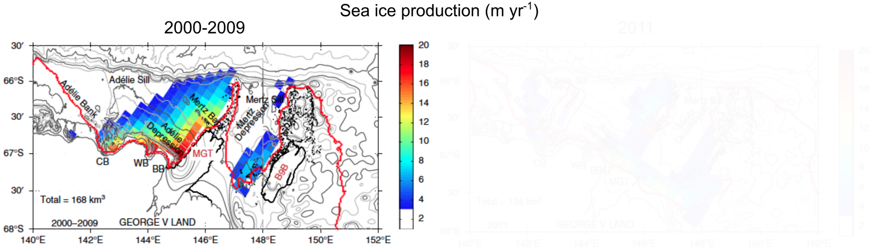
Australian-Antarctic Basin

Mertz Glacier Polynya

- high rate of sea ice production due to intense latent heat polynya

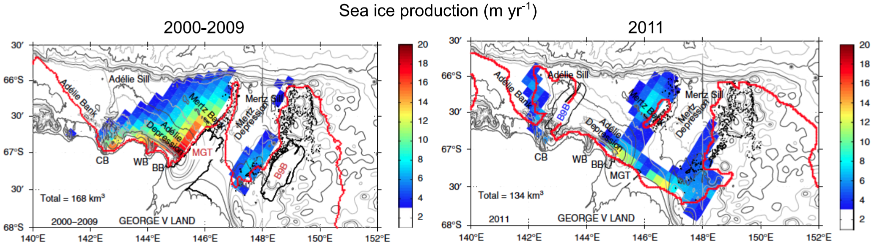


Tamura et al. 2012, Nat. Com.

Australian-Antarctic Basin

Mertz Glacier Polynya

- high rate of sea ice production due to intense latent heat polynya
- the Mertz Glacier Tongue calved in 2010, loosing almost half of its size
- 14-20 % decrease in sea ice production



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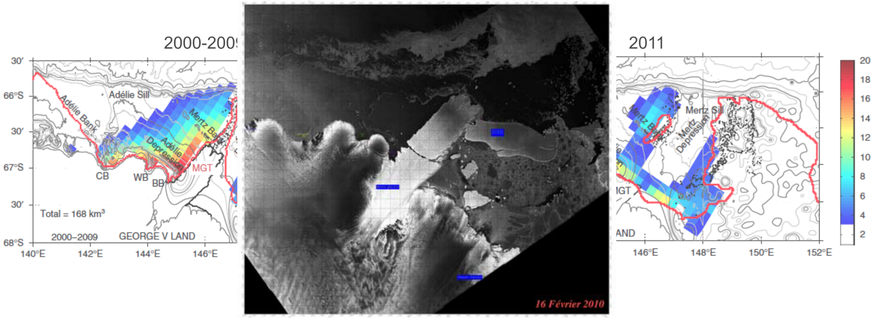
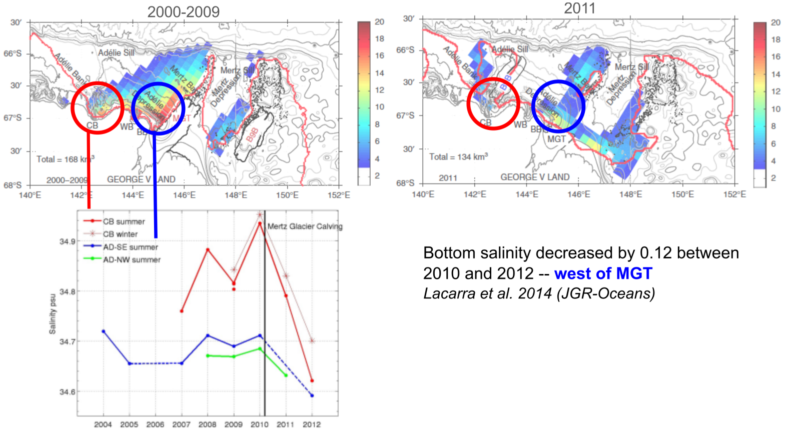


Lescarmontier 2012 (PhD thesis)

Australian-Antarctic Basin

Mertz Glacier Polynya

- water properties have changed on the continental shelf following the calving event



Bottom salinity decreased by 0.12 between 2010 and 2012 -- **west of MGT**

Lacarra et al. 2014 (JGR-Oceans)

Model description

- Based on a modified version of the Regional Ocean Modeling System (ROMS; *[Shchepetkin and McWilliams 2005]*
- Includes:
  - ocean/ice shelf thermodynamics *[Dinniman et al. 2007]*
    - Three-equations formulation *[Holland and Jenkins 1999]* based on heat and salt conservation, and a linearised version of the freezing temperature (as a function of salinity and pressure)

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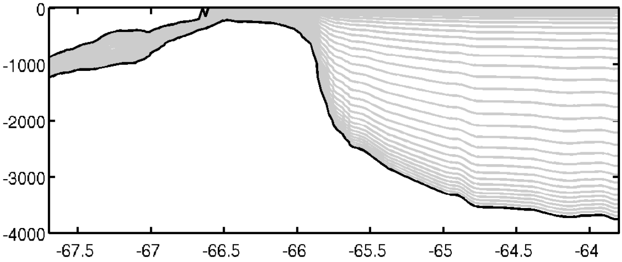
    - terrain following vertical levels with higher resolution at the bottom and the surface (below ice shelf) to better estimate the melt rate



Model description

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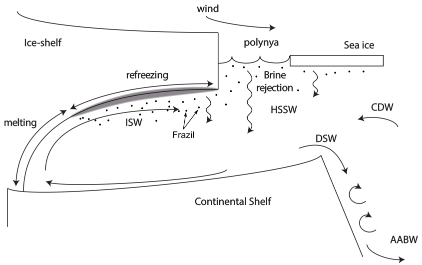
- Includes:
  - ocean/ice shelf thermodynamics *[Dinniman et al. 2007]*
  - frazils thermodynamics *[Galton-Fenzi et al. 2012]*
    - growth of frazil crystal increases salinity
    - efficient at removing supercooling



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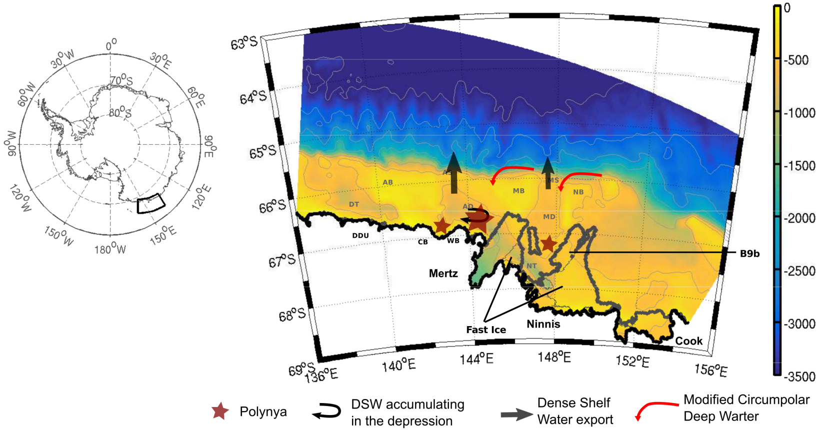
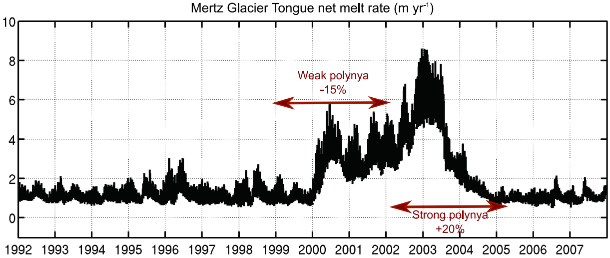
- Forcing:
  - ECCO2 climatology for lateral boundaries (potential temperature, salinity and velocity)
  - surface forcing: heat and salt fluxes from SSM/I observations *[Tamura et al. 2016]*

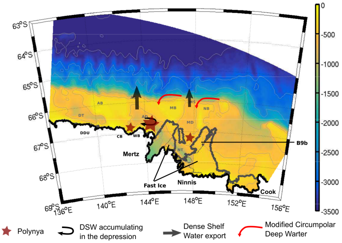
Mertz model and general ocean circulation



Interannual variability pre-calving – 1992-2007



Cougnon et al. 2013 (JGR-Oceans)



Next step:

- How a change in icescape impacts on the melt rate and local oceanography?

Model description – pre- and post-calving set up

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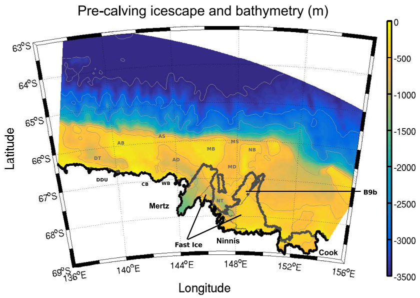
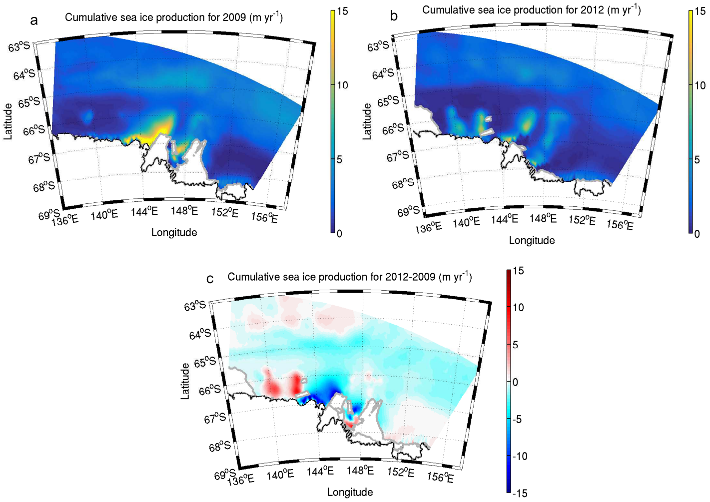
- Includes:
  - ocean/ice shelf thermodynamics *[Dinniman et al. 2007]*
  - frazils thermodynamics *[Galton-Fenzi et al. 2012]*
- Forcing:
  - ECCO2 climatology for lateral boundaries (potential temperature, salinity and velocity)
  - surface forcing: heat and salt fluxes from SSM/I observations *[Tamura et al. 2016]*
- **Pre- and post-calving set up:**
  - using one year climatology as forcing (spinup and run)
  - 2009 pre-calving and 2012 post-calving (relatively stable icescape)
  - simplified analytic tidal forcing at the lateral boundaries (M2, S2, K1, O1 are adjusted to be periodic in 14 days *[Pingree and Griffiths 1981]*)

PRE- AND POST-CALVING ICESCAPE

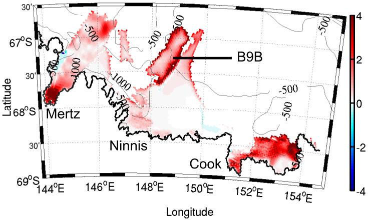


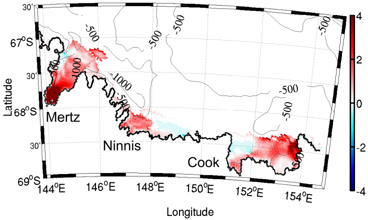
PRE- AND POST-CALVING CUMULATIVE SEA ICE PRODUCTION



PRE- AND POST-CALVING BASAL MASS LOSS

Basal melt rate (m yr^{-1})

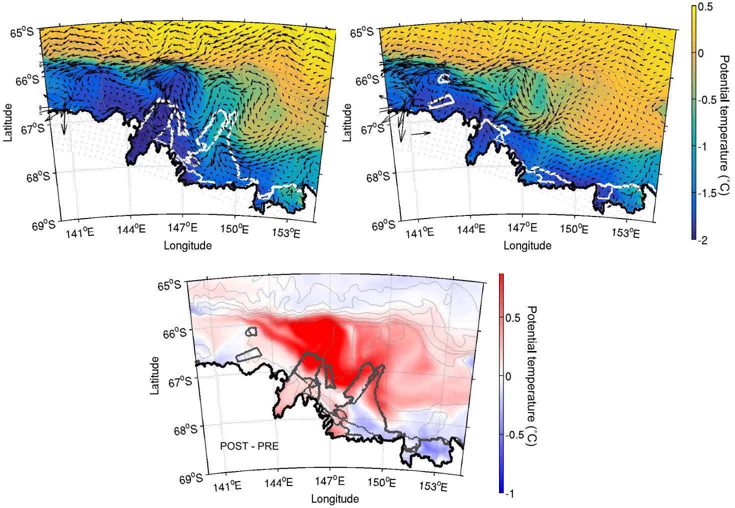




Ice Shelf	PRE (Gt yr^{-1})	POST (Gt yr^{-1})	% area change	% mass loss change
Total	23.8±2	20.8±3	-19%	-14%
Mertz	**5.6±0.5**	**6.0±1.0**	**-42%**	-7%
Ninnis	0.6±0.4	1.3±0.8	0%	+117%
Cook	7.3±1.4	4.5±1.7	0%	-38%
B9B	**5.3±0.9**	0.6±0.1	-69%	-89%

- Total mass loss does not change significantly
- Mertz mass loss unchanged while the area available for melting has decreased by 42% (increased in area-averaged melt of 89%)
- Most of the Mertz basal melting occurs for ice deeper than 900 m:
  - 40% of the mass loss pre-calving
  - 54% of the mass loss pre-calving
- B9B pre-calving has a similar basal mass loss than the Mertz

Pre- and post-calving ocean circulation and depth averaged potential temperature



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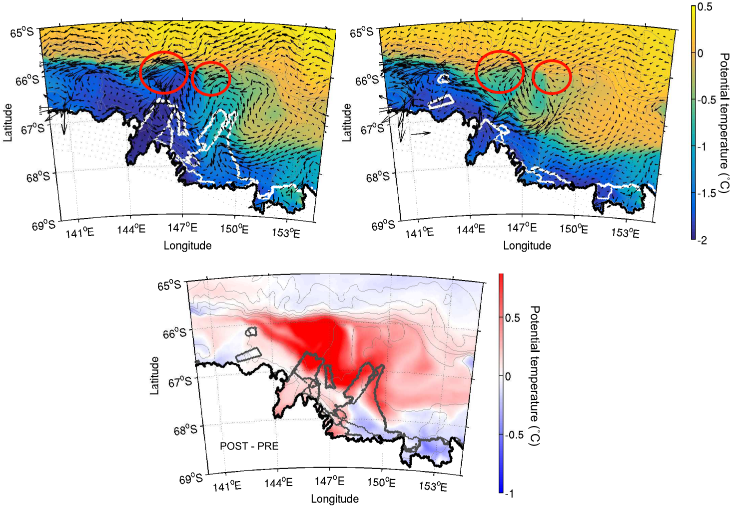

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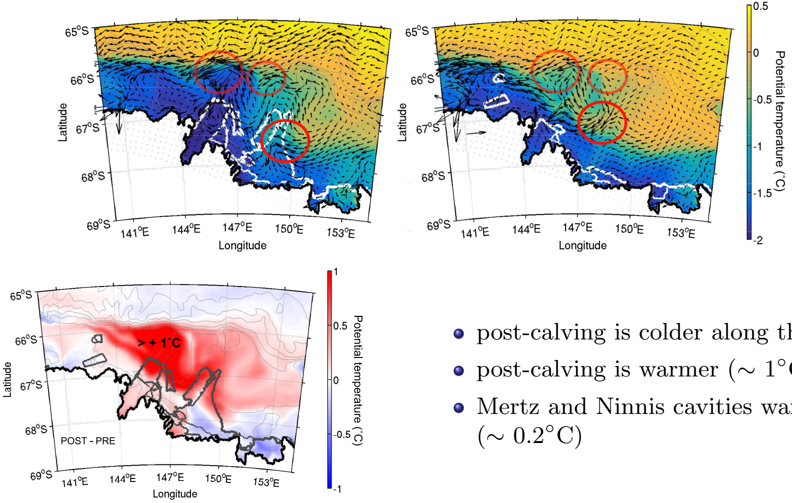
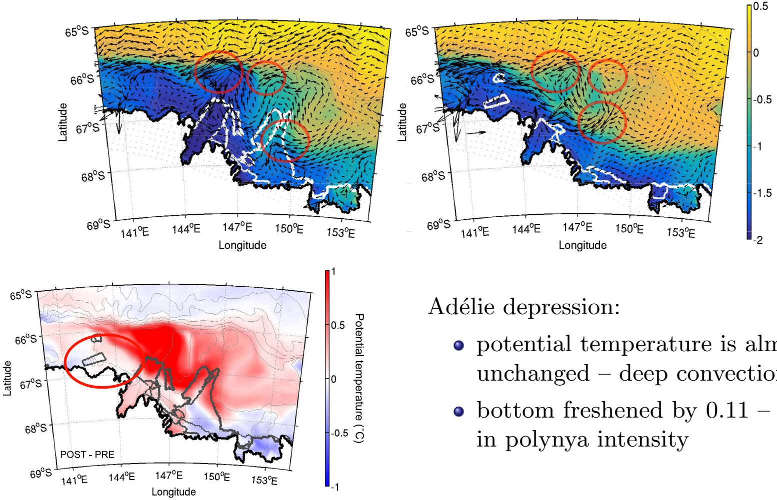


- post-calving is colder along the coast
- post-calving is warmer (∼ 1°C)
- Mertz and Ninnis cavities warmer by (∼ 0.2°C)

Pre- and post-calving ocean circulation and depth averaged potential temperature



Adélie depression:

- potential temperature is almost unchanged – deep convection
- bottom freshened by 0.11 – decrease in polynya intensity

Summary

- B9B iceberg in the model (pre-calving simulation) insulate and precondition water masses that reach the Mertz and Ninnis cavities
- change in icescape and associated decrease in sea ice production lead to an increase in area-averaged basal melt rate of the Mertz Glacier Tongue of 89% (sustained basal mass loss)
- no significant changes in basal mass loss (fresh water input) for the entire model domain (pre- and post-calving)
- polynya activity post-calving along the coast west of the Mertz Glacier Tongue is still strong enough to homogenise the whole water column
  - Dense Shelf Water within the Adélie depression (main reservoir pre-calving) decreased by $\sim 80\%$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CSIRO
ACE CRC ANTARCTIC CLIMATE & ECOSYSTEMS CRC
Australian Government
Department of the Environment and Energy
Australian Antarctic Division