In Dronning Maud Land, Antarctica, the ocean melts >1.5x as much ice as previously thought

Basal Mass Balance [m/a]: -10, -5, 0, 5, 10
Subglacial Meltwater Flux [m³/s]: 0.2, 0.278, 0.356, 0.434, 0.5
Bathymetry/Bed elevation [m]: < -3250, -3000, -2000, -1000, 0, > 250
Surface Velocity [m/a]: -20, 60, 140, + 180, Ice-shelf mask

Rignot et al (2013)
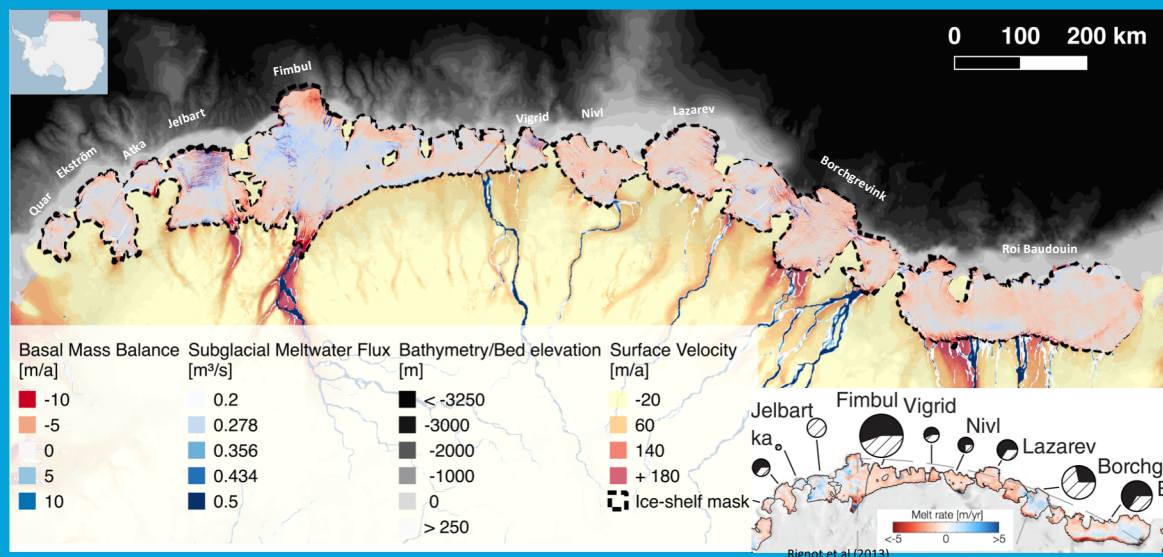
Basal melting of Dronning Maud Land ice shelves twice as high as previously estimated

Sophie Berger (1), Veit Helm (1), Tore Hatterman (2), Niklas Neckel (1), Quentin Glaude (3,4), Ole Zeising (1), Sainan Sun (3), Frank Pattyn (3) and Olaf Eisen (1,5)

(1) Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research , Germany (2) Norwegian Polar Institute, Norway, (3) Laboratoire de Glaciologie, Université libre de Bruxelles, Belgium (4) Centre Spatial de Liège, Université de Liège, Belgium, (5) Department of geosciences, University of Bremen, Bremen, Germany

$$\frac{DH}{Dt} = \quad -H\left(\nabla \cdot \vec{u}\right) \quad + \dot{M}_s \quad + \dot{M}_b$$

Key points
- Melt rates around -0.91 and -0.74 m/a for Dronning Maud Land with TanDEM-X and CryoSat-2 for the 2013-2016 period.
- TanDEM-X is noisier but with greater spatial details.
- Melting varies on different spatial scales
  - Between ice shelves (e.g. Fimbul vs Borchgrevink)
  - Within ice shelves : calving front, grounding line, interior
  - Sub-kilometric scale
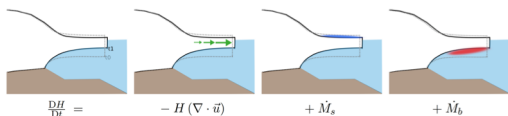
Motivation
- Antarctica is the biggest and most uncertain potential contributor to sea-level rise
- The Antarctic ice sheet virtually loses all its ice in contact with the ocean.
- Basal melting
  - Is the most important process of ice loss.
  - Varies a lot spatially

→ we need to detect/monitor basal melting
  - At high resolution
  - From space (exhaustive coverage)

Method
- Mass conservation with Lagrangian (moving) coordinates

1. Lagrangian thickness change:
   - Hydrostatic thickness Archimedes' Principle: change in thickness ↔ change in elevation From TanDEM-X of 2013 and 2016 + from CryoSat-2
   - Matching: moving framework normalized cross-correlation + velocities
2. Ice-flow divergence
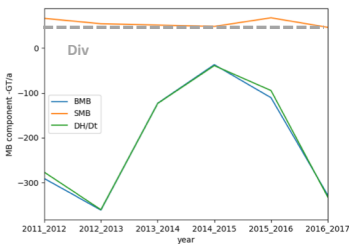3. Surface Mass Balance

Processing challenges
- Linear ramps in TanDEM-X elevations
- Unwrapping on ice-shelf edge (moving front, ice separated by sea)
- Absolute elevation from TanDEM-X
  - DEM referenced to external DEM
  - Dh/Dt calibrated with CryoSat-2 Dh/Dt
- Dronning Maud Land is a stable region
  → close to detection limit of elevation changes

Proof of concept
- Roi Baudouin Ice Shelf
- Melting connected to ice-shelf morphology
- Berger et al (2017), The Cryosphere.

Ice shelf	Ice-shelf area (km2)	TanDEM-X	CryoSat-2	Rignot2013
Baudouin	33143.8	-35.35	-31.46	-14.1
Borchgrevink	21629.6	-24.8	-20.68	-7.5
Lazarev	8571.63	-9.04	-8.23	-6.3
Nivl	7321.5	-10.47	-10.6	-3.9
Vigrid	2096.02	-2.19	-0.59	-3.2
Fimbul	40955.5	-17.63	-15.11	-23.5
Jelbart	10846.3	-7.46	-0.69	1
Atka	2004.77	-1.21	-0.36	0.5
Ekstrom	6870.83	-3.47	-2.61	-4.3
Quar	2133.85	-1.51	-1.48	-1.4
TOTAL	135574	-113.4	-91.92	-62.7

BMB (Gt/a)

Annual Mass Balance with CryoSat2

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

belspo — Belgian Science Policy Office

ULB UNIVERSITÉ LIBRE DE BRUXELLES

CSL