Progress towards community ensemble estimates of Antarctic ice shelf basal melting and evaluation with observations

Ben Galton-Fenzi
Sea level rise equivalent per catchment
Different types of ice and sea level

How good are simulations of melting?

- Projections need to include the oceans influence on the ice sheets
- Basal melting is an integrator of ocean state and useful for monitoring change

Gwyther et al. 2012; Cook et al. 2018. In prep

- Where do models agree and disagree?
- Are the trends and variability captured?
- How do we get the best from observations of basal melting and ocean heat supply?
NECKLACE: International effort to measure basal melting of ice shelves with ApRES

NECKLACE = Network for the Collection of Knowledge on meLt of Antarctic iCe shElves
Ocean and Ice sheet Ensembles (OIE) project

Motivation:

- Ocean-driven Antarctic mass loss large uncertainty in future SLR
- No broad-scale comparison and evaluation of ocean-ice sheet interaction models and observations exist

Aims:

- A coordinated multi-model comparison of ice-shelf/ocean models, before comparing ice sheet models and then coupled models.
- Integration and coordination between modelling and observational studies
- Improve detection and attribution of ice sheet mass change and ocean state.
Phase 1 WCRP-CliC MISOMIP extension

Realistic Ice Shelf Ocean Model IntercomParison: R-ISOMIP

- Assess present-day basal melt rate and ocean states
- Guide the future direction of observations on and beneath ice shelves and sea ice
- Provide ensemble estimates of basal melting under future climate
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Realistic Ice Shelf Ocean Model IntercomParison: R-ISOMIP

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- Guide the future direction of observations on and beneath ice shelves and sea ice
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- Develop appropriate parameterisations for ice sheet models (e.g. ISMIP6 ...)
- Inform ice sheet model ensembles and guide future ice sheet observations, particularly for the coupled system
**R-ISOMIP**

- Evaluation of ensembles with observations: e.g. ApRES and others.

- *Needs coordinated ocean state and melt observation synthesis for evaluation!*

- Initial evaluation of existing models by early 2019. Regional and other whole-Antarctic?

<table>
<thead>
<tr>
<th>Ocean Model</th>
<th>Host Institute</th>
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<tbody>
<tr>
<td>MOM</td>
<td>GFDL, USA</td>
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<td>MITgcm/ECCO2</td>
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<td>POP2X / MPAS-O</td>
<td>LANL/Potsdam, USA/Germany</td>
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<td>MetROMS - CAISOM</td>
<td>MetNO/ACE CRC, Norway/Australia</td>
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<td>COCO</td>
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<td>Grenoble, France</td>
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<td>ROMS - ACIMA</td>
<td>ODU, USA</td>
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<tr>
<td>Emulator</td>
<td>LANL/Potsdam, USA/Germany</td>
</tr>
</tbody>
</table>
Comparison of published results

Antarctic mass loss from observations and models

- Richter 2018
- Liu 2015
- Depoorter 2013
- Rignot 2013
- Hellmer 2004
- Timmermann 2012
- Kusahra 2013
- Dinniman 2015
- Schodlock 2016
- Mathiot 2017
- Naughten 2018 (MetROMS)
- Naughten 2018 (FESOM)
Example: Comparison of bias in basal mass loss

Naughten et al. 2018. GMD.
Example: Comparison of water mass properties

Water masses in ice-shelf cavities (2002–2016 average)

(a) Filchner–Ronne Ice Shelf
(b) Eastern Weddell region
(c) Amery Ice Shelf
(d) Australian sector
(e) Ross Sea
(f) Amundsen Sea
(g) Bellingshausen Sea
(h) Larsen ice Shelves
(i) All ice Shelves

MetROMS
FESOM (low-res)
FESOM (high-res)

% volume

ISW, MCDW, HSSW, LSSW, AASW

Naughten et al. 2018. GMD.
Naughten et al. 2018. GMD.

**Amundsen Sea**

- **(a) Ice-shelf melt rate (m yr⁻¹)**
  - MetROMS
  - FESOM (low-res)
  - FESOM (high-res)

- **(b) Bottom water temperature (°C)**

- **(c) Bottom water salinity (psu)**

- **(d) Vertically averaged ocean velocity (m s⁻¹): Pine Island Glacier ice shelf**

**Australian sector**

- **(a) Ice-shelf melt rate (m yr⁻¹)**
  - MetROMS
  - FESOM (low-res)
  - FESOM (high-res)

- **(b) Bottom water temperature (°C)**

- **(c) Bottom water salinity (psu)**

- **(d) Vertically averaged ocean velocity (m s⁻¹): Totten Ice Shelf**
Closing thoughts and discussion points

- Large multi-institute multi-model comparisons allow models and parameterisations to be improved, but needs coordinated in situ observations for evaluation: e.g. ApRES
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- Pragmatic considerations. Storage and data handling and effort: RDSI
Example: resolution dependence

- Many more warm water intrusions at 4 km
- Are bathymetric troughs more important than eddies?
- 2 km - 1 km?

Richter et al. in-prep.
Example: influence of physical processes, e.g. tides

- Large impact on cold water ice shelves
- Which tidal melt mechanisms contribute most?
- Integrated effect small: 57 Gt/yr (4%)

Richter et al. in-prep.
Limits to using models to inform observations

Key process/tool for linking ice/ocean interaction - needs investment

- Parameterisation and model uncertainties limit ability to constrain ocean properties via observations of processes, e.g. basal melting.
- How do we get the best from observations of basal melting and ocean heat supply? e.g. ApRES
Limits to using models to inform observations

- Limitations in model framework requires simplifications
- Approximations and assumptions within parameterisations
- Unresolved processes
- Poorly understood processes
- Model complications, including choices of boundary and initial conditions
- Different model architectures, numerics, parameterisations
Multi-model multi-institutional comparison projects

MISOMIP (Marine Ice Sheet-Ocean Model Intercomparison Project)
- CliC targeted activity: David Holland lead. Meetings in 2014, 2016 and future 2018. So far three sets of idealised experiments
- ISOMIP+: Ice-shelf/Ocean Model Intercomparison
- MISMIP+: Marine Ice Sheet Model Intercomparison
- MISOMIP: coupled Marine Ice Sheet/Ocean Model Intercomparison
Multi-model multi-institutional comparison projects

ISMIP6 (Ice Sheet Model Intercomparison for CMIP6)

- CliC targeted activity: Tony Payne and Helene Seroussi links with MISOMIP

- Bring ice sheet model intercomparisons in line with CMIP community

- Feedbacks and forcings from Atmosphere-Ocean-GCMs

- Needs basal melting parameterisations/downscaling for ice sheet models for ocean forcings