Antarctic freshwater fluxes into ocean models

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May 2023

Freshwater fluxes into the ocean =

Precipitation (snow+rain) – Evaporation

Sea-ice melt – Sea-ice formation

Ice-shelf melt + Iceberg melt

Surface runoff + Blowing snow

Subglacial runoff

Surface salinity corrections

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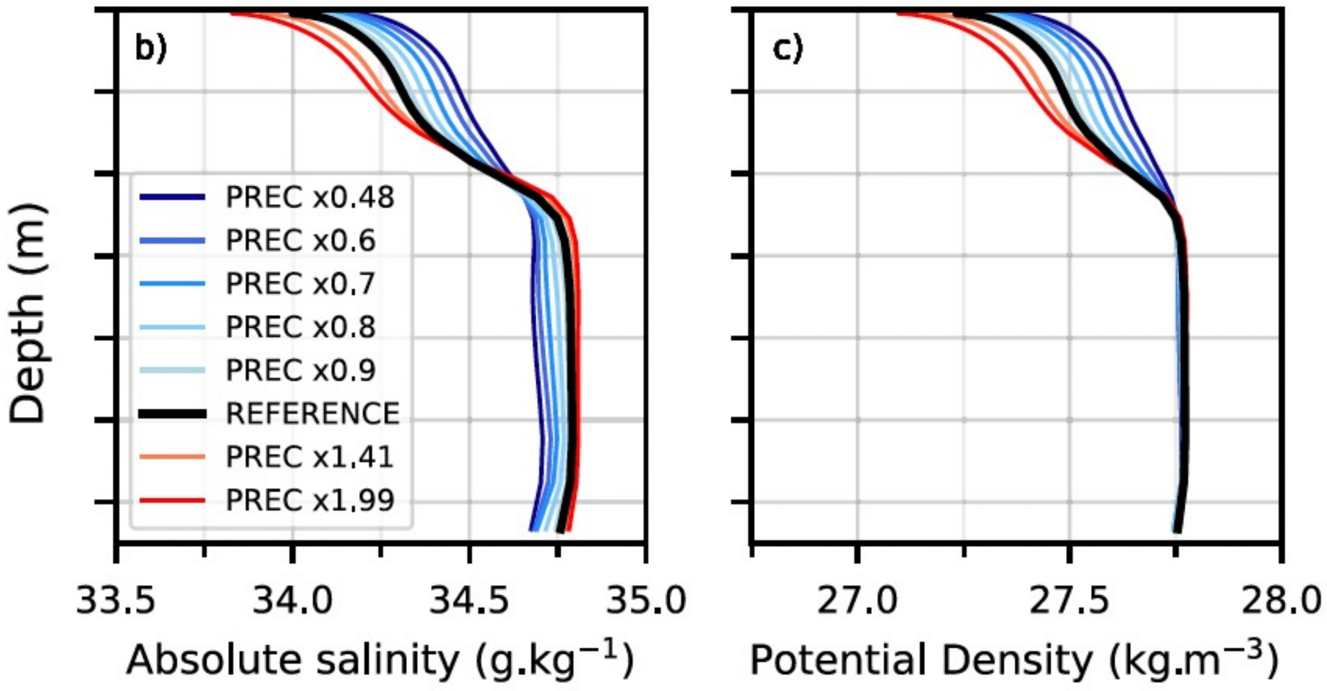
Focus of OCEAN:ICE

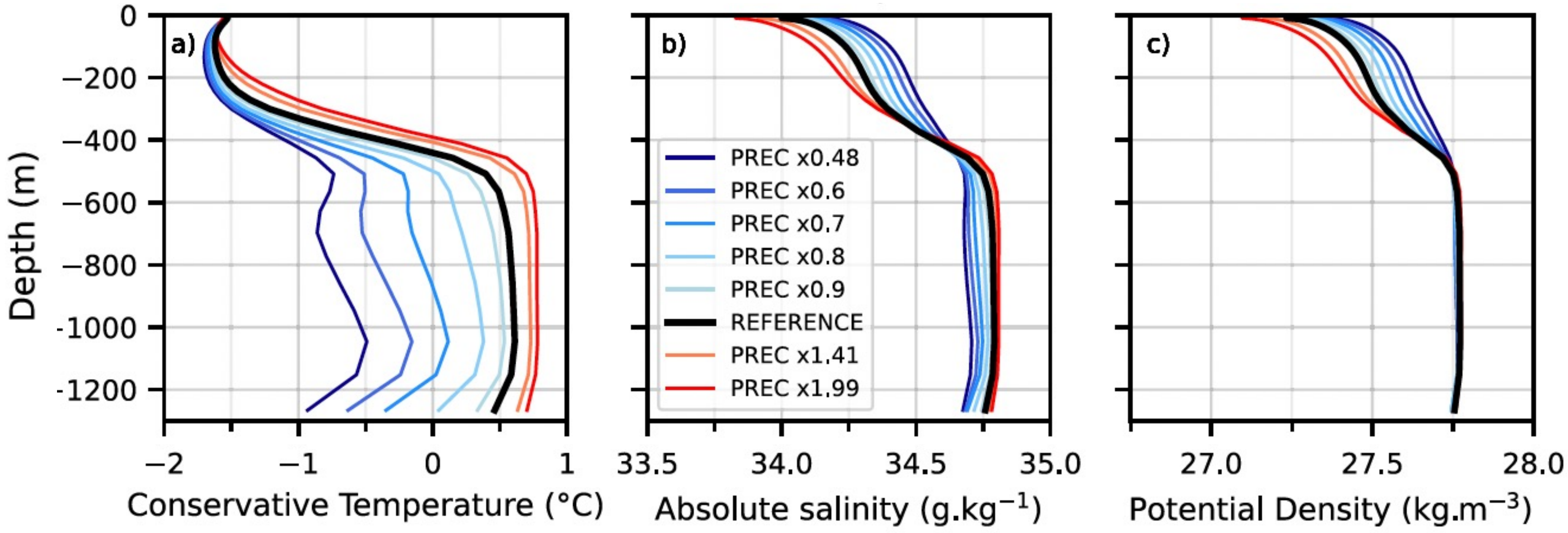
Freshwater fluxes into the Southern Ocean control vertical heat exchanges

<u>Example</u>:
Ocean response to modified precipitation in the Amundsen Sea



Caillet et al. (2023)

Freshwater fluxes into the Southern Ocean control vertical heat exchanges

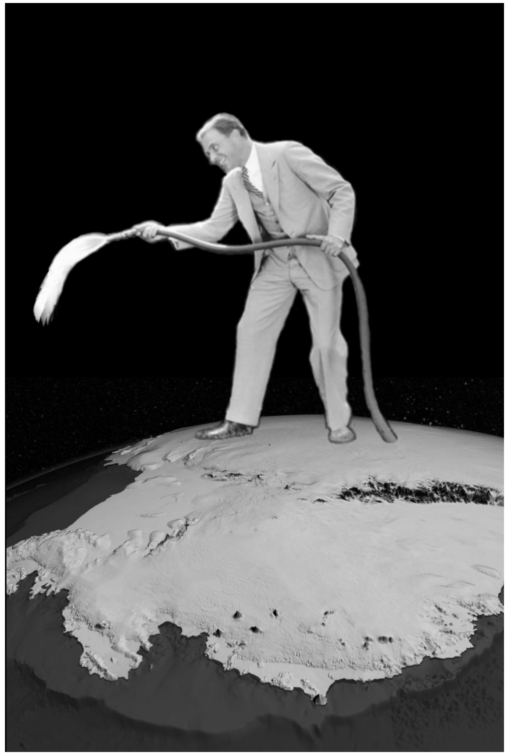


Freshwater fluxes have strong impacts on Antarctic Seas and ice shelf melting

Caillet et al. (2023)

Hosing experiments have received a lot of interest

(glacial freshwater spread at the Southern Ocean surface)



In general, additional freshwater into the ocean leads to :

⇒ Reduced formation of Antarctic Bottom Water (AABW)
e.g. *Menviel et al. (2010), Li et al. (2023)*

⇒ Increased sea ice concentrations
e.g. *Bintanja et al. (2013, 2015), Swart & Fyfe (2013)*

⇒ Warming of ice shelf cavities
e.g. *Phipps et al. (2016), Purich and England (2023)*

However, there is a lack of consensus on the ocean response

due to :

- Differences in ocean model resolutions and parameterisations.
- Large differences in the amounts of injected glacial freshwater.
- Accounting or not for latent heat of melting ice.

will be addressed in the Southern Ocean Freshwater release model experiments Initiative (SOFIA).

- Large differences in the spatio-temporal patterns of freshwater fluxes:
  - Various distributions along the ice sheet edge.
  - Various distributions equatorward.
  - Various vertical distributions (usually at the surface).
  - Various ways to estimate the temporal evolution of glacial freshwater release.

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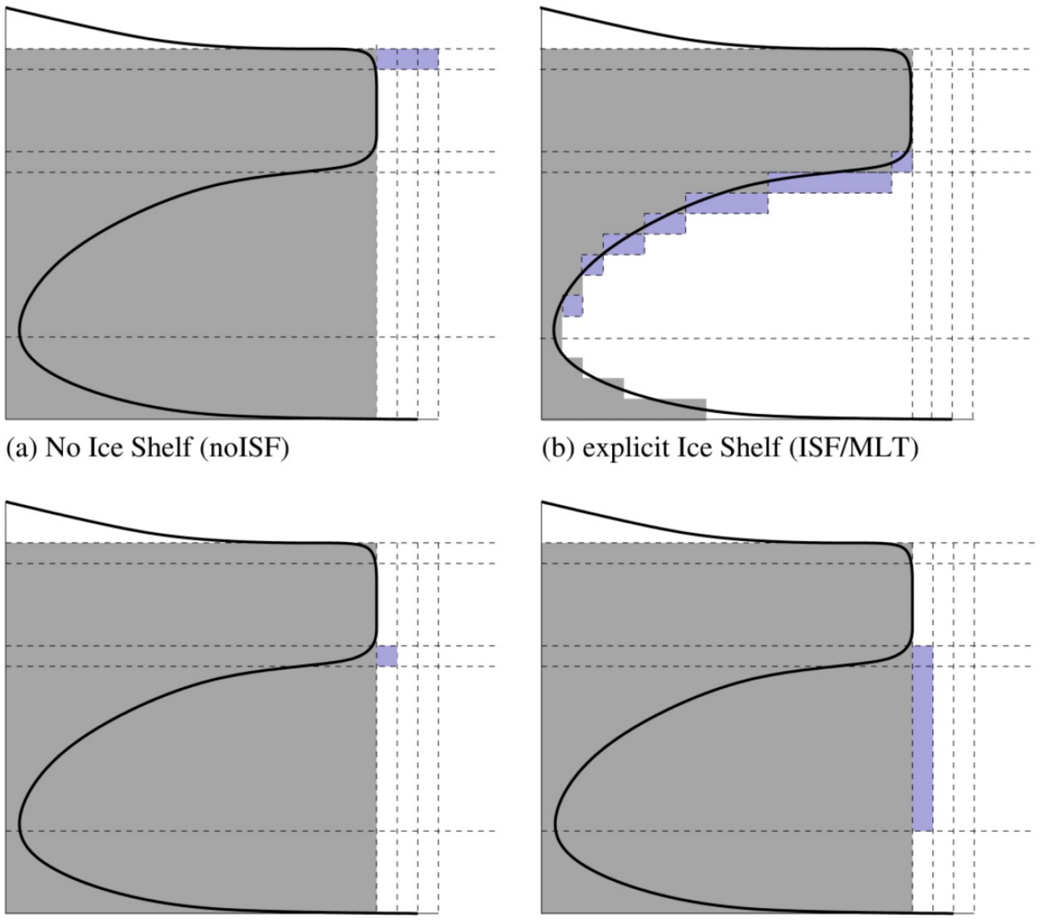
There has been progress on the way to inject ice-shelf freshwater



(a) No Ice Shelf (noISF)

(b) explicit Ice Shelf (ISF/MLT)

(c) Ice Shelf param. (BG03)

(d) Ice Shelf param. (PAR)

Location of ice shelf melt water input

interface (ice/atmosphere, ice/ocean or bedrock/ocean)

Masked area (land, ice sheet or closed ice shelf cavity)

Mathiot et al. (2017)

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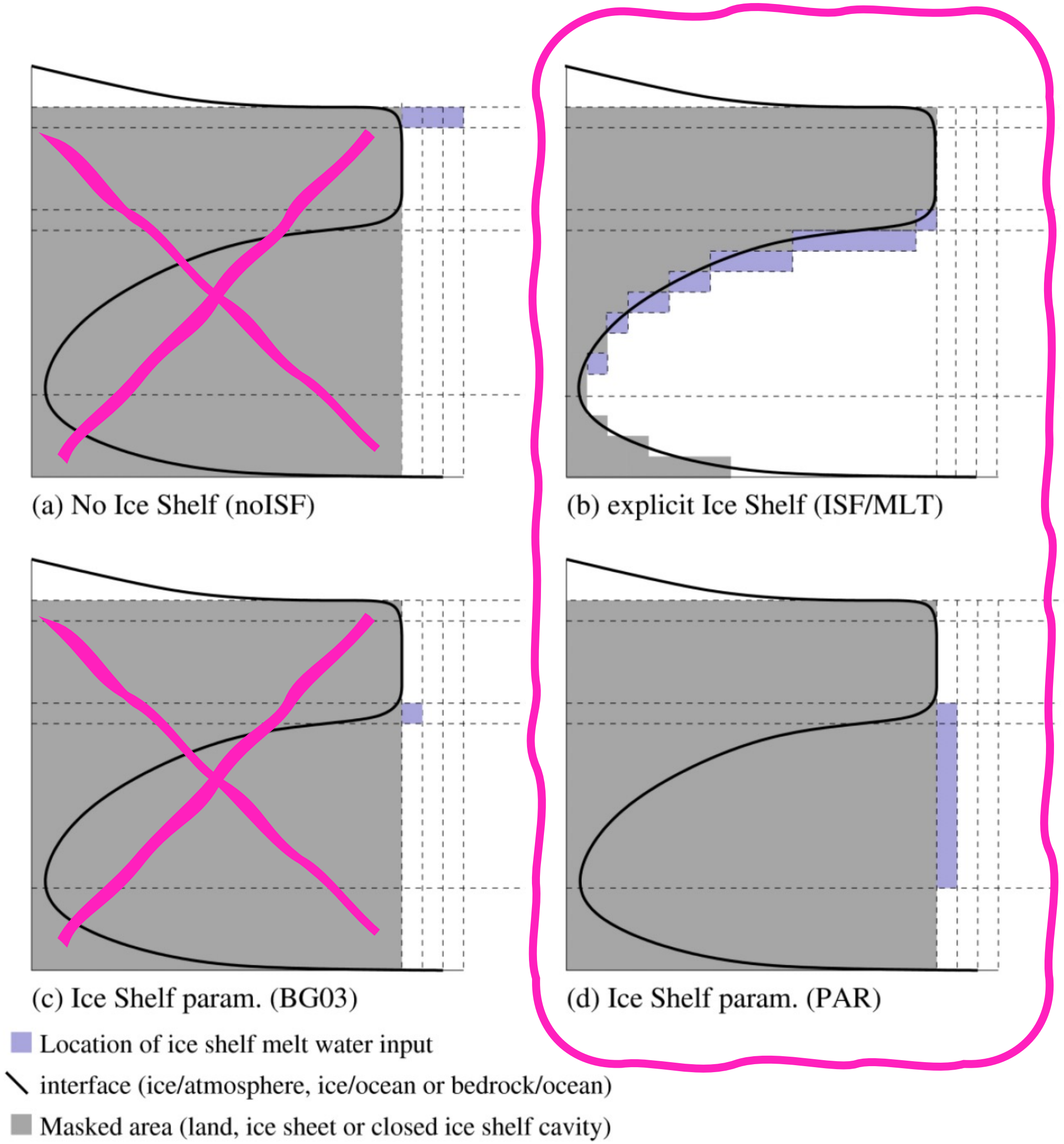
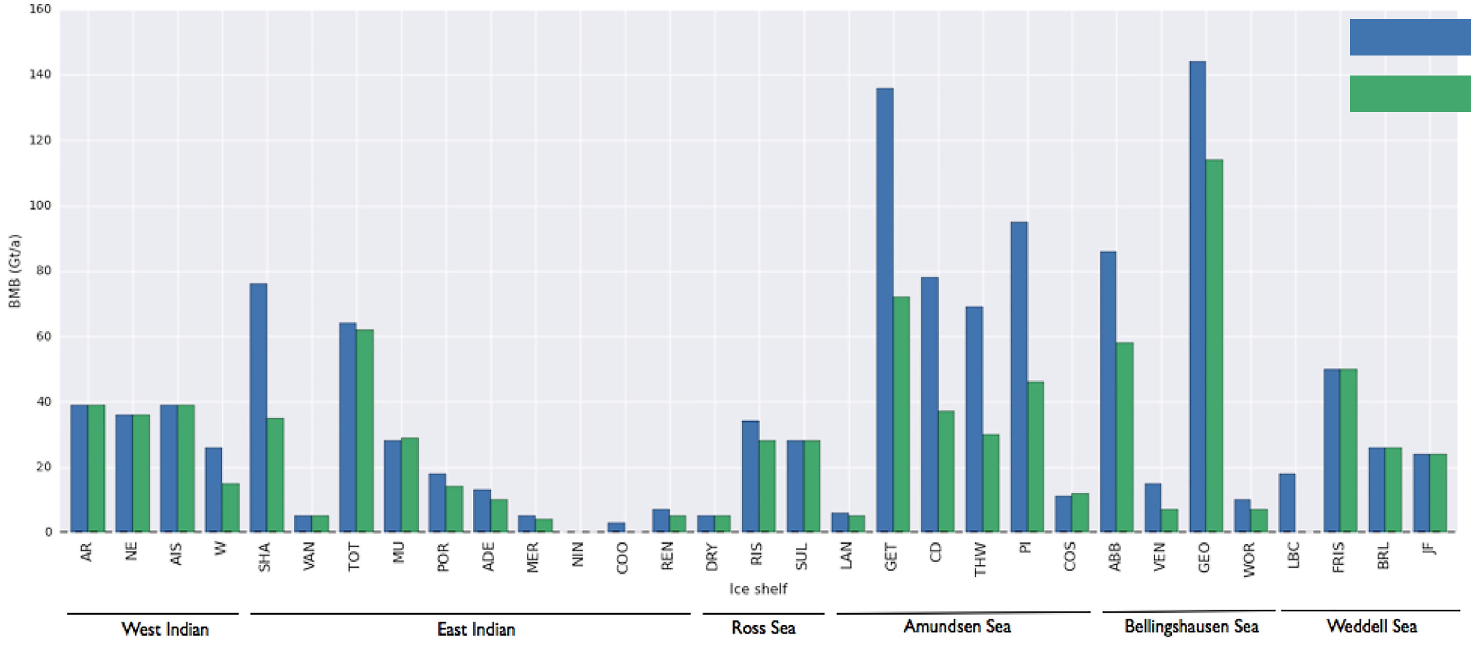
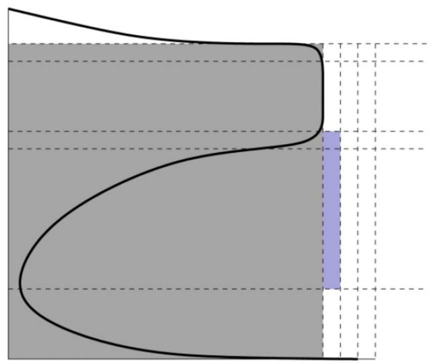


Only two valid ways to distribute the ice-shelf freshwater

Mathiot et al. (2017)

Example: sea ice trend attributed to ice shelf melting





Merino et al. (2018)

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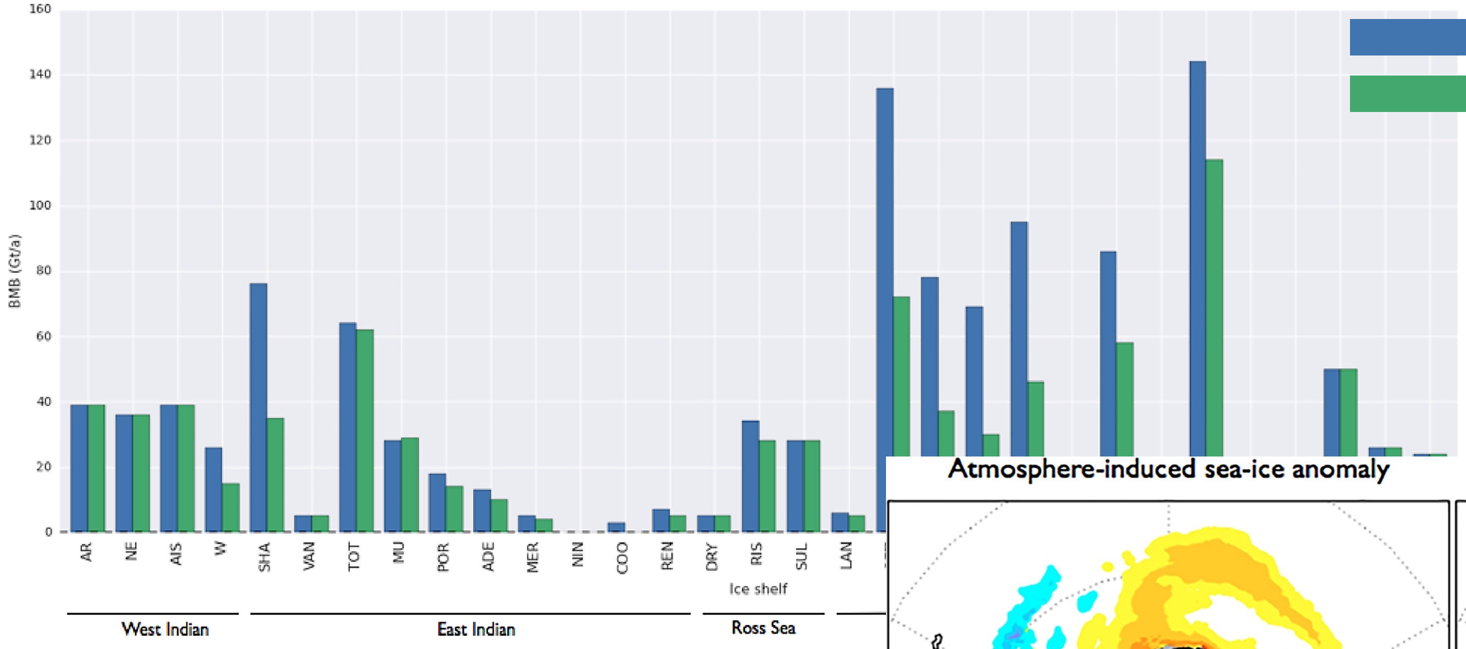
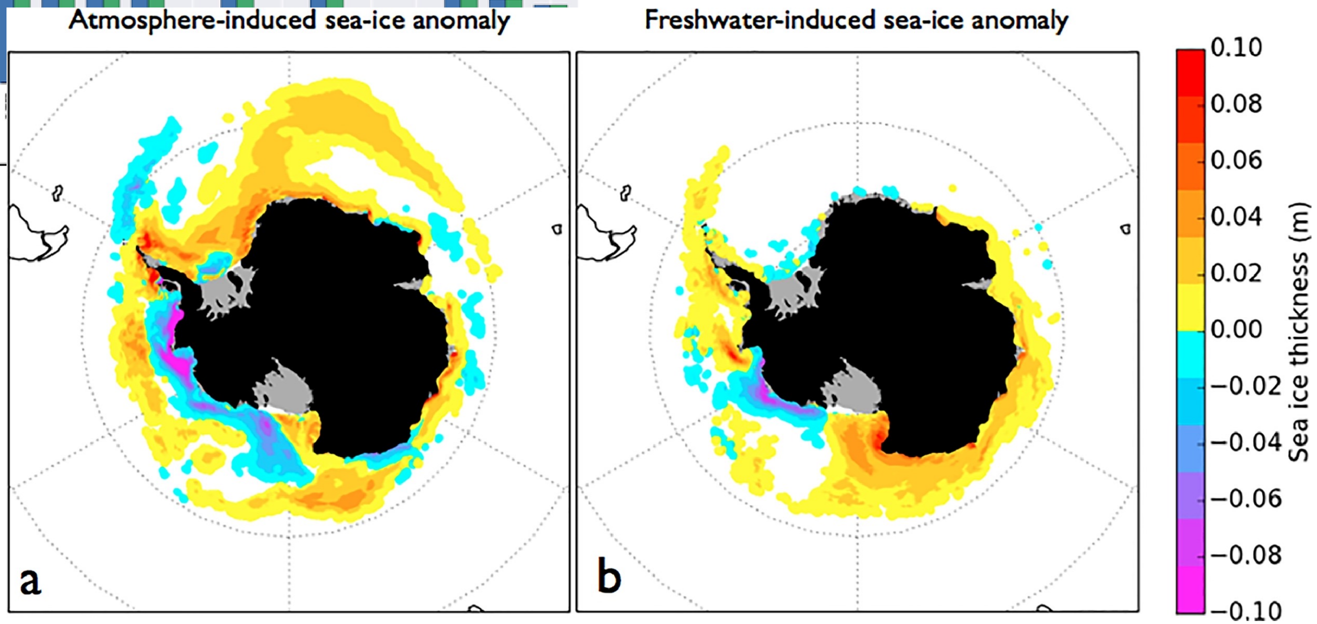
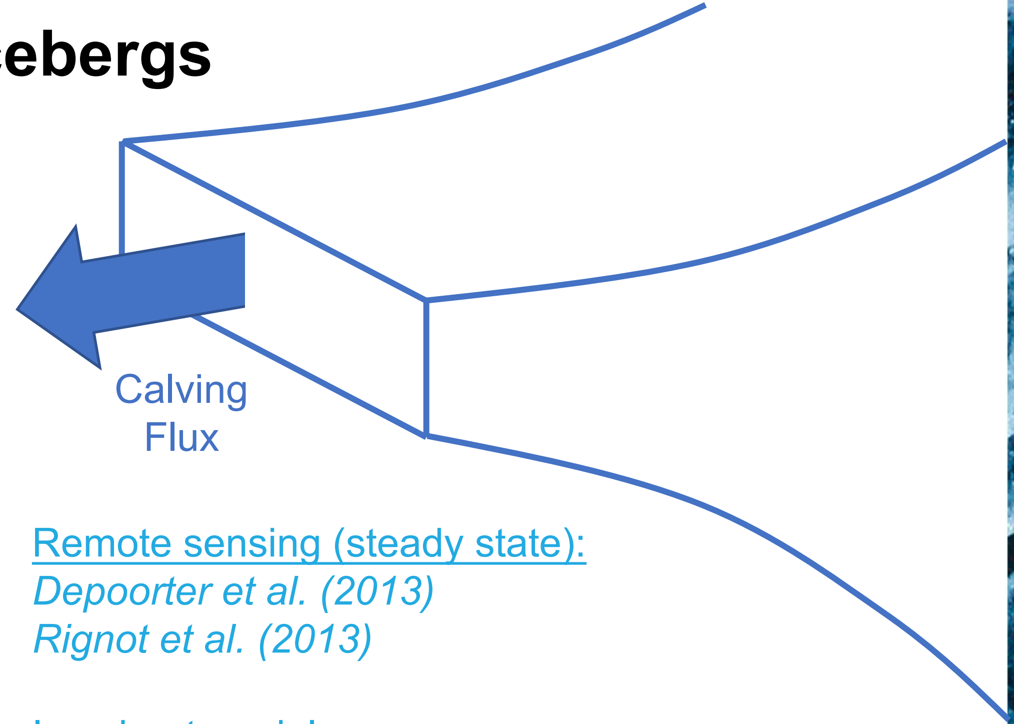




Merino et al. (2018)

… and progress on the way to represent icebergs



Remote sensing (steady state):
Depoorter et al. (2013)
Rignot et al. (2013)

Ice-sheet model:
Smith et al. (2021)

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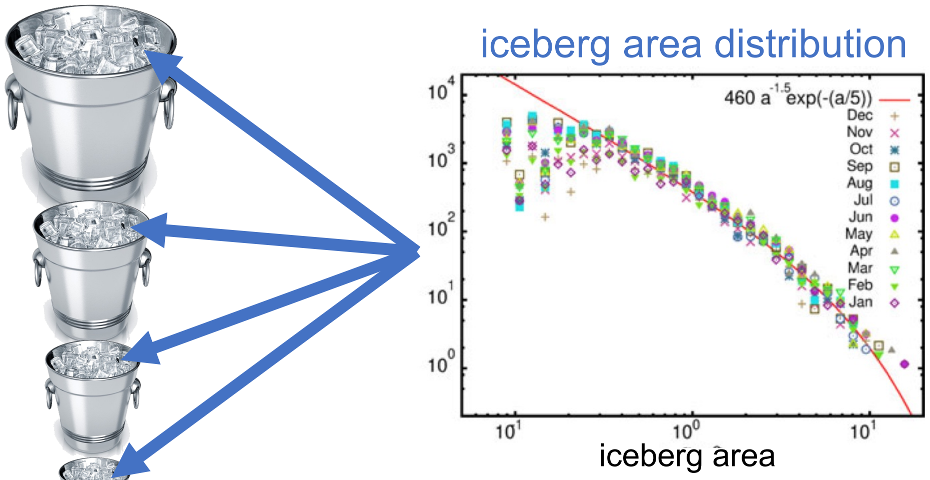
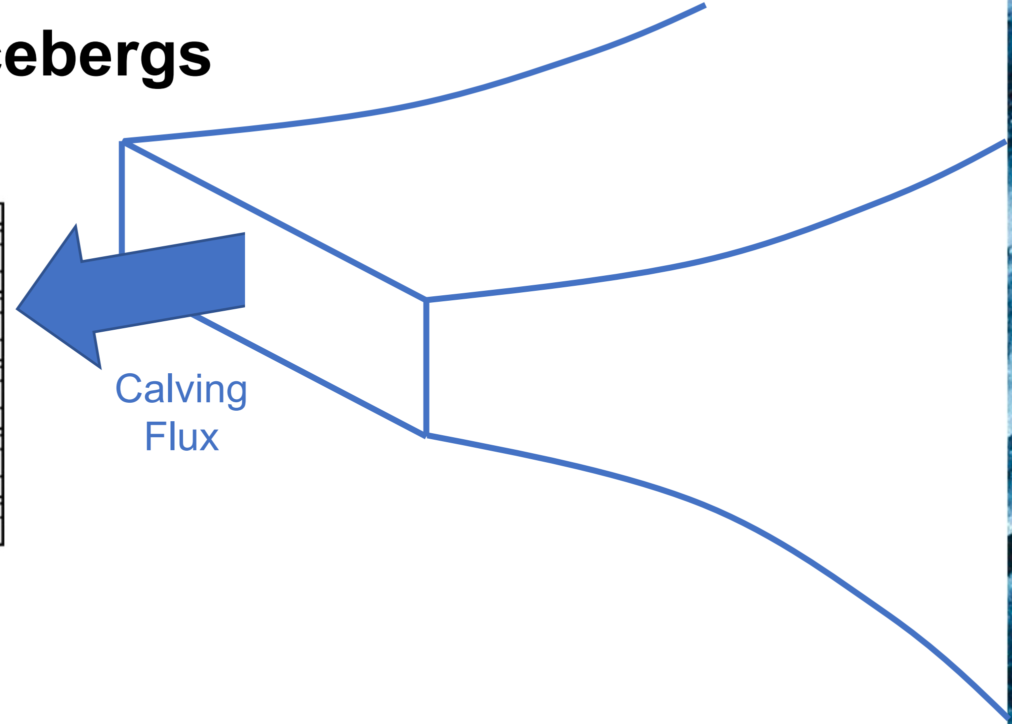
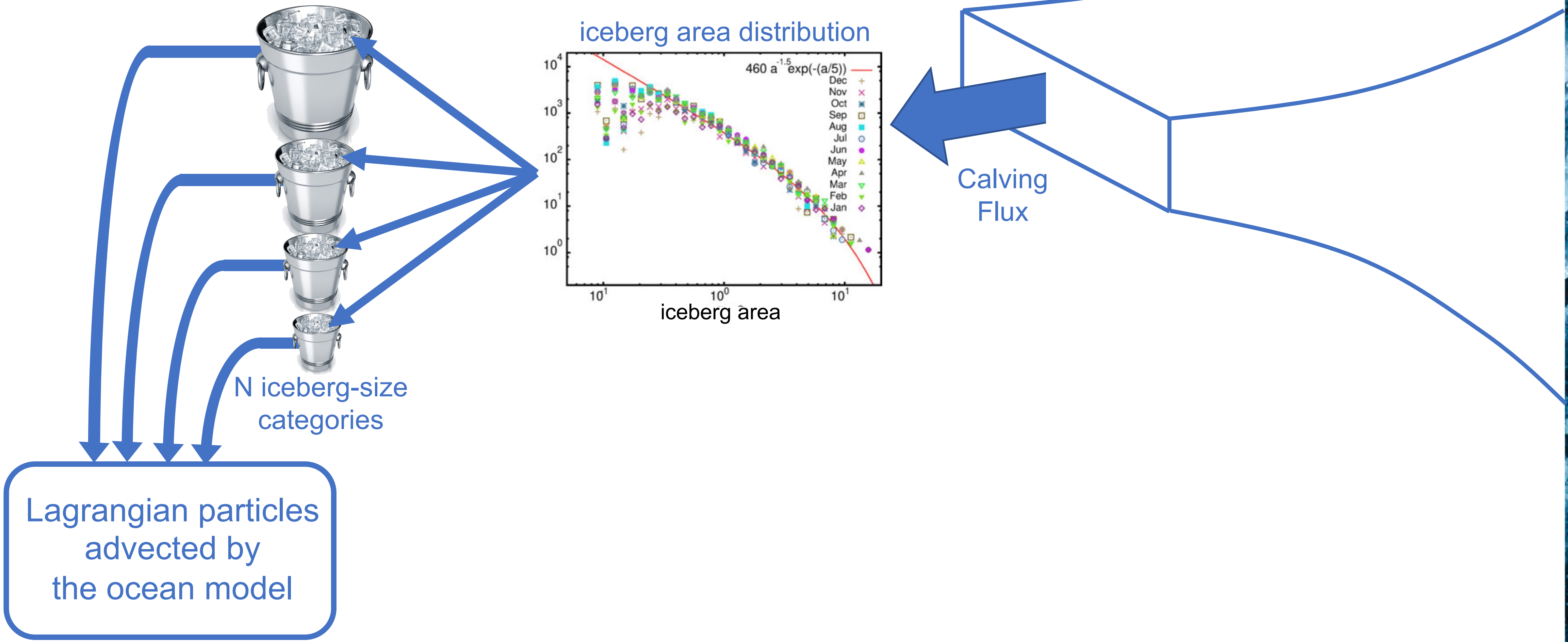


N iceberg-size categories



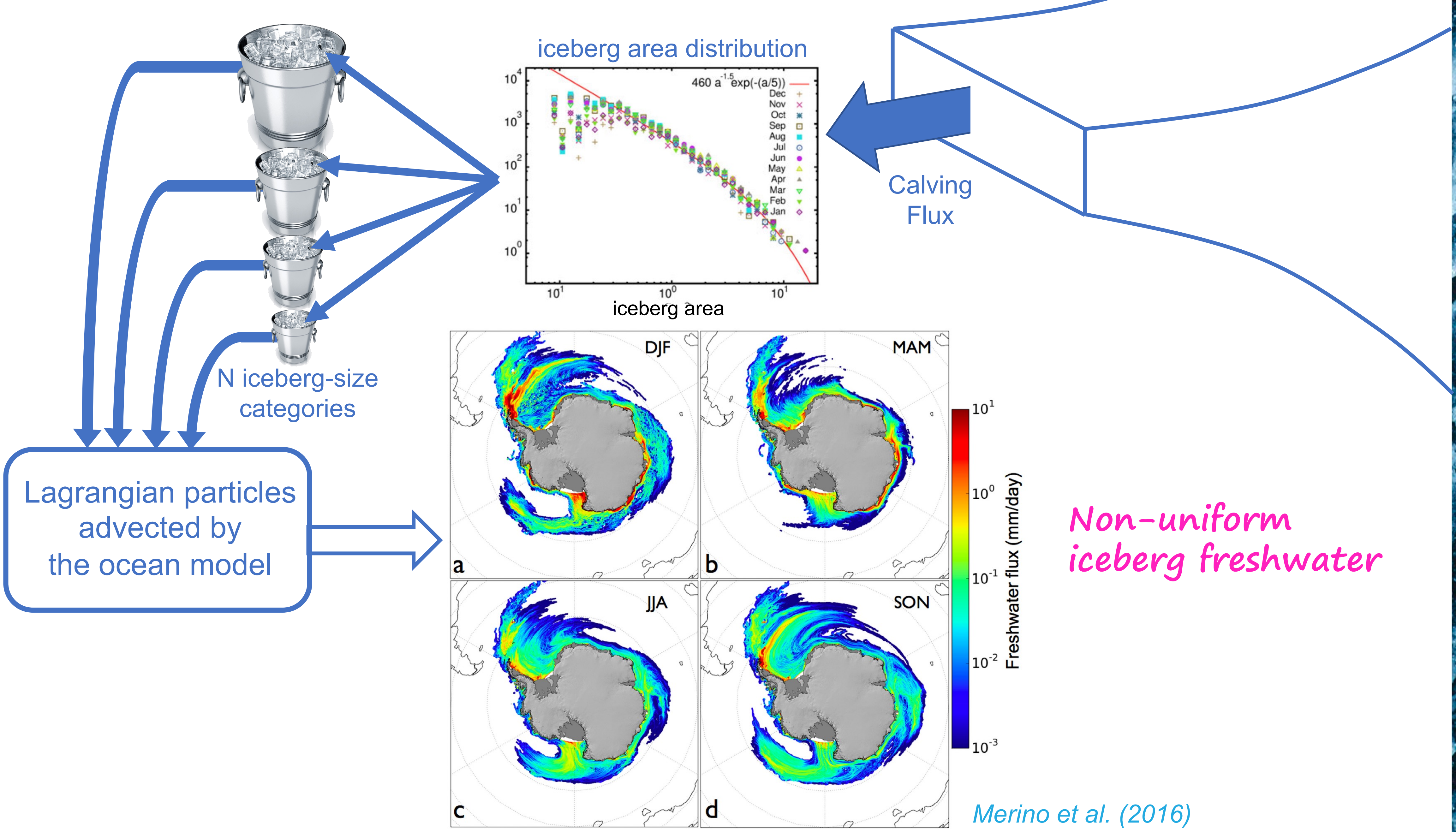
Åström et al. (2021)
Gladstone et al. (2001)

… and progress on the way to represent icebergs



Martin and Adcroft (2010)

… and progress on the way to represent icebergs



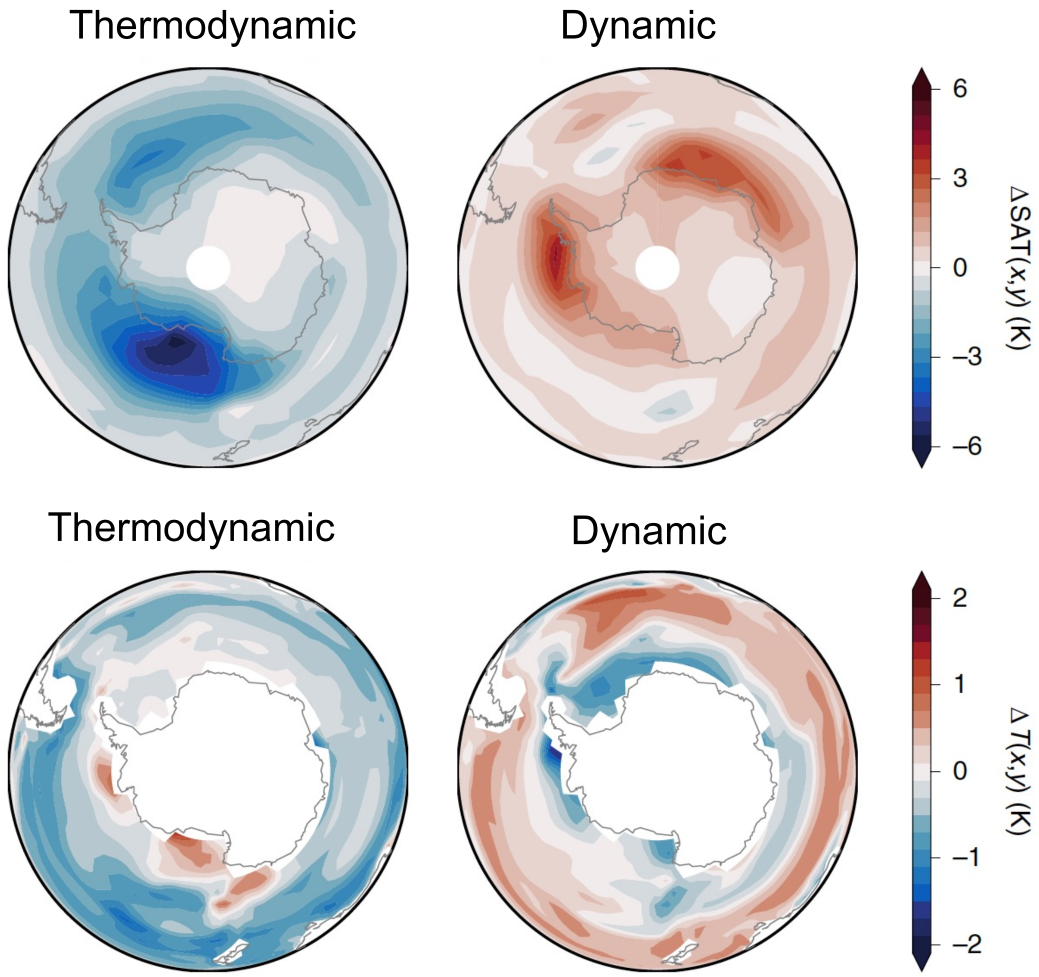
Non-uniform iceberg freshwater

Merino et al. (2016)

Lagrangian models have started to be used in climate simulations

Influence of icebergs on surface air temperature

Influence of icebergs on ocean temperature at 400m depth



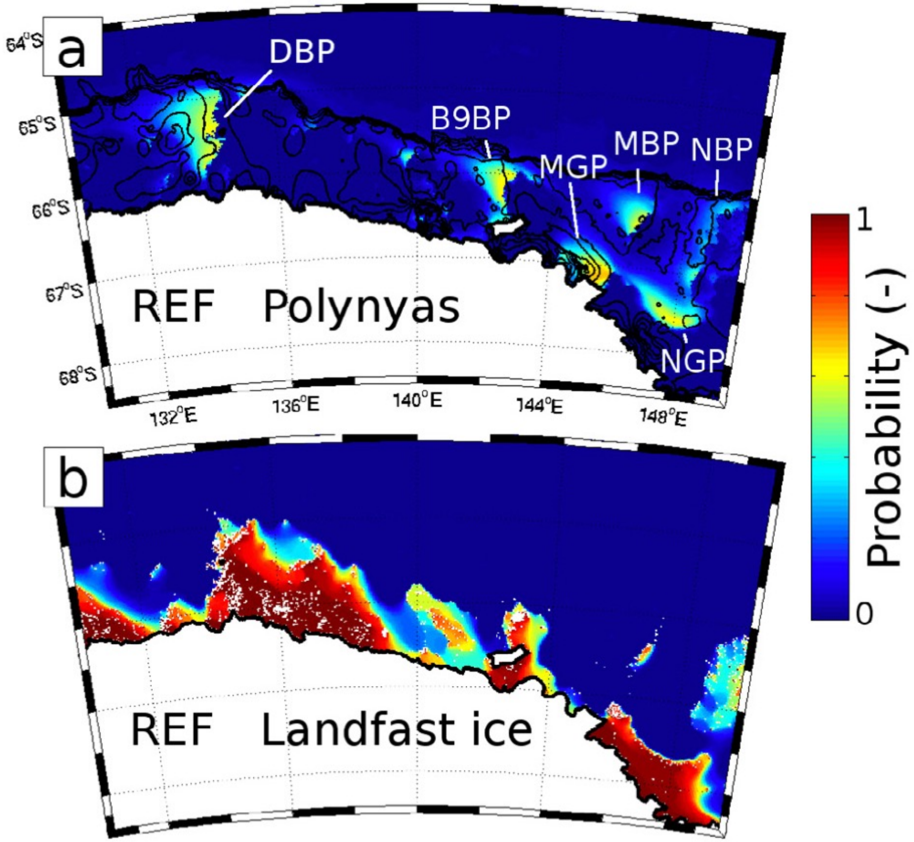
LOVECLIM projections to 2100 under RCP8.5

Schloesser et al. (2019)

New developments planned in OCEAN:ICE : iceberg grounding

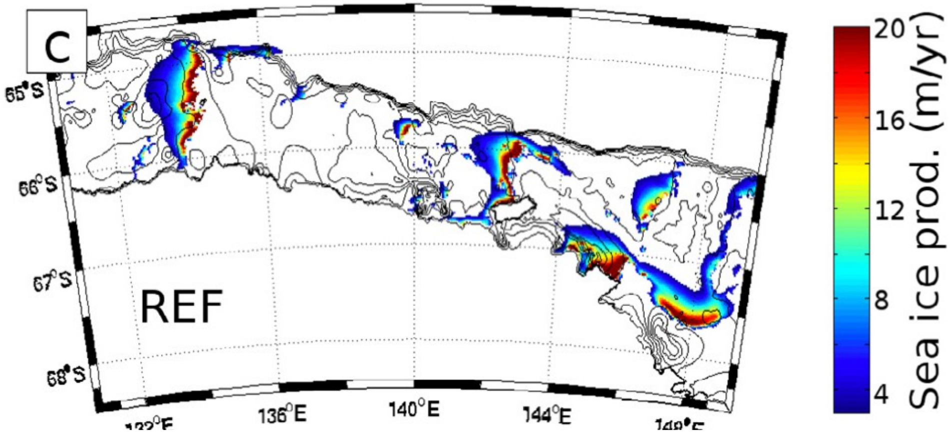
Many icebergs grounded on shallow ridges

⇒ Favor fast ice (sea ice fasten to bergs)
⇒ Polynyas
⇒ Ocean deep convection

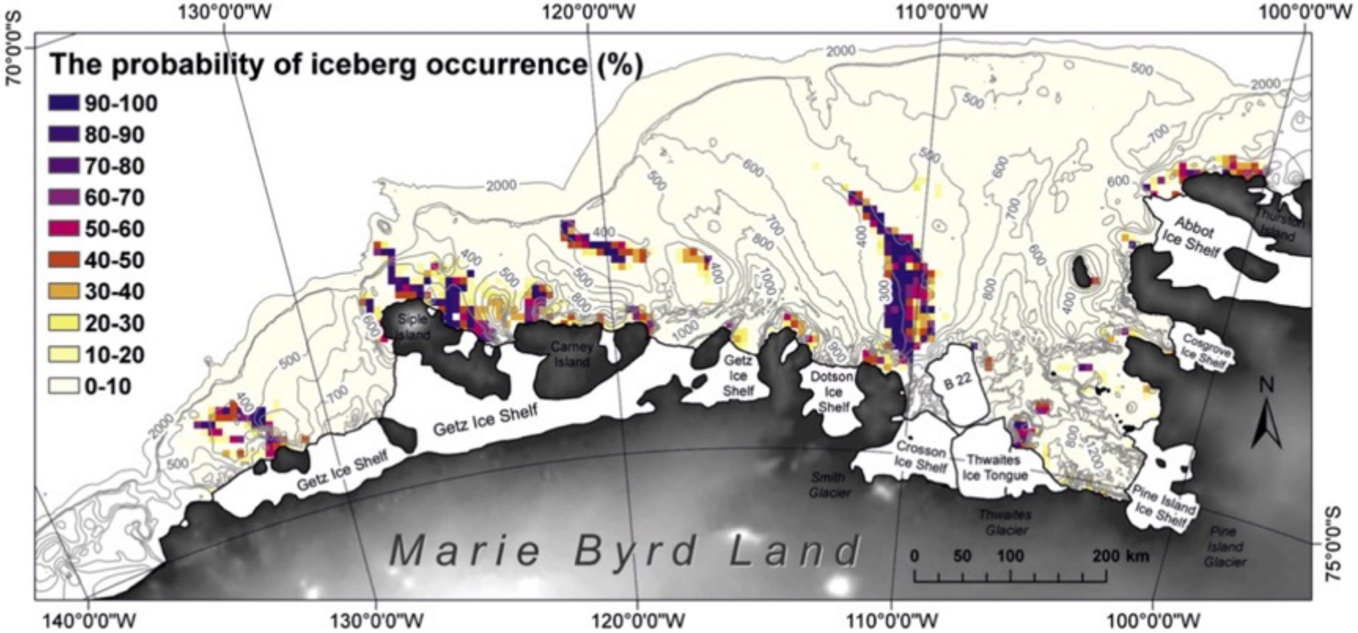


Simulations of the D'Urville Sea, East Antarctica

Huot et al. (2021)



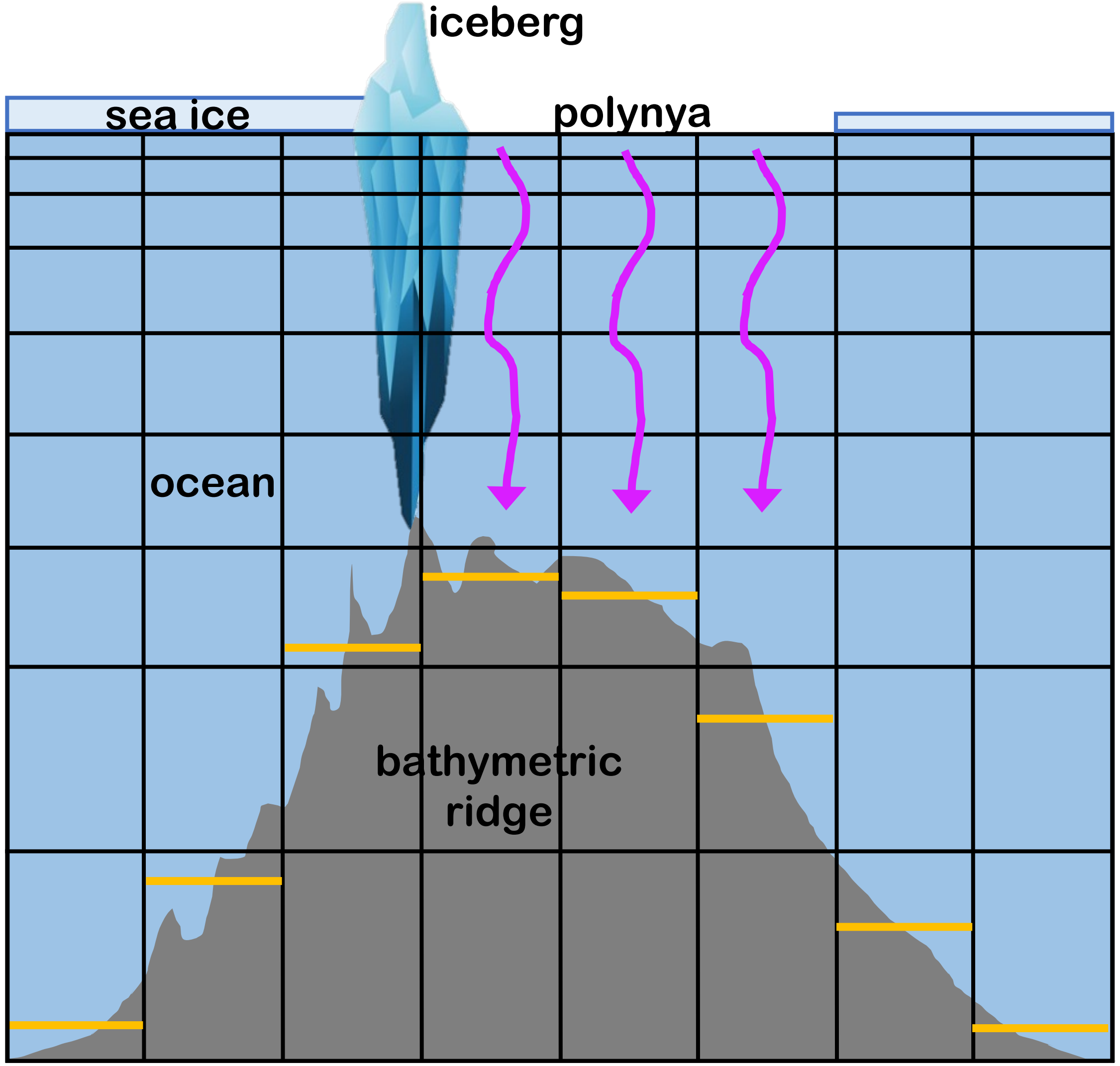
Similar processes all around Antarctica, e.g. in the Amnundsen Sea :



Mazur et al., 2017

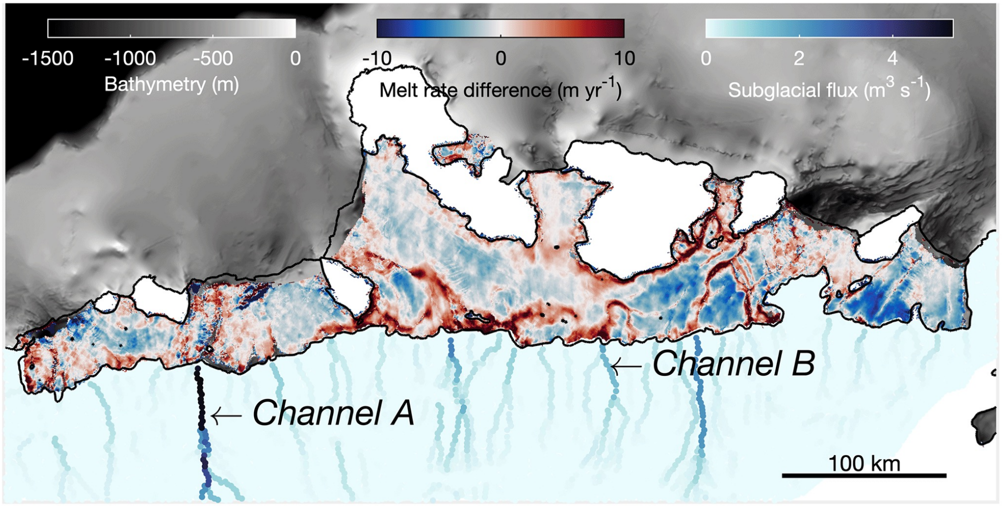
Main technical objectives :

- Better representation of iceberg thickness (depending on ice-shelf thickness).
- New scheme for iceberg interaction with subgrid-scale bathymetry.
- New scheme for the iceberg interaction with sea-ice (synergy with other projects).



Importance of subglacial runoff for the ocean

Subglacial runoff is likely a relatively weak freshwater flux but has a direct influence on basal melt rates



Getz Ice Shelf

Melt rate deficit attributed to subglacial runoff.

Subglacial flux from the GlaDS model.

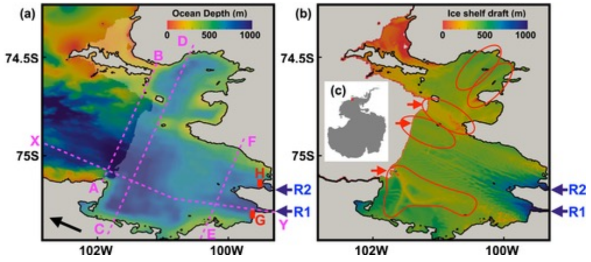
Wei et al. (2020)

First ocean simulations with subglacial runoff in Antarctica :

Pine Island :

⇒ much higher melt rate at the grounding line (locally from 80 to 150 m/yr).

⇒ Weak influence on the cavity-averaged melt rate (~ +5%).

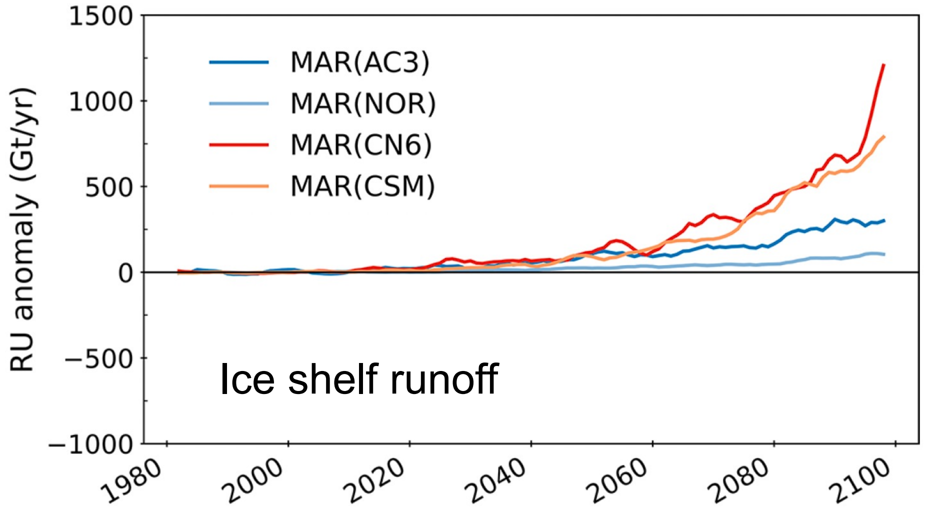


Nakayama et al. (2021)

Importance of surface runoff for the ocean

Present-day surface runoff is orders of magnitudes weaker than ocean-induced melt, and therefore usually not used to drive ocean models.

Future surface melt increases exponentially with temperature and may become important in the future:

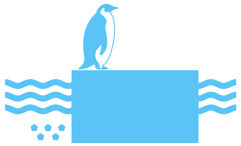


Kittel et al. (2021)

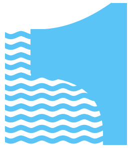
> work in progress
(Chistoph Kittel)

Summary

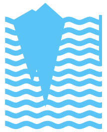
- Freshwater fluxes are key drivers of changes in water mass properties on the continental shelf



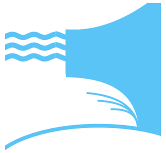
- Variability of ice-shelf freshwater (released at depth) has impacts on sea ice trends.



- Lagrangian iceberg models greatly improve the realism of freshwater fluxes, and their interaction with bathymetry and sea ice will be developed in OCEAN:ICE.



- Subglacial runoff increases basal melt rates near grounding lines.



- Surface runoff may become a significant freshwater source in warmer climate projections.

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