EGU2021 The Southern Ocean's connection to sea ice and ice shelves

Landfast sea ice in the Totten Glacier region in East Antarctica

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Introduction

Def : Landfast sea ice (fast ice) is stationary sea ice which forms and remains attached to the shore or between grounded icebergs. Here, defined as sea ice with a 2-week mean velocity lower than 0,005 m/s.

Fast ice plays an important rôle in Antarctica :

- decreases the transfer of heat, moisture, momentum between the atmosphere and the underlying ocean (Johnson et al., 2012).
- Is linked with the polynya location. Because fast ice blocks westward sea ice advection, polynyas are frequently formed on the western side of fast ice (Massom et al., 1998)
- Forms an important interface between the Antarctic ice sheet and the ocean (Massom and Stammerjohn, 2010).

When taken into account, fast ice is either simulated with fast ice parameterisations or prescibed.

Parameterisations :

- The tensile strength and basal stress parameterisations reproduce the fast ice formation mechanisms, the ice arching and the grounding of sea ice ridges, respectively (Lemieux et al., 2015, 2016).

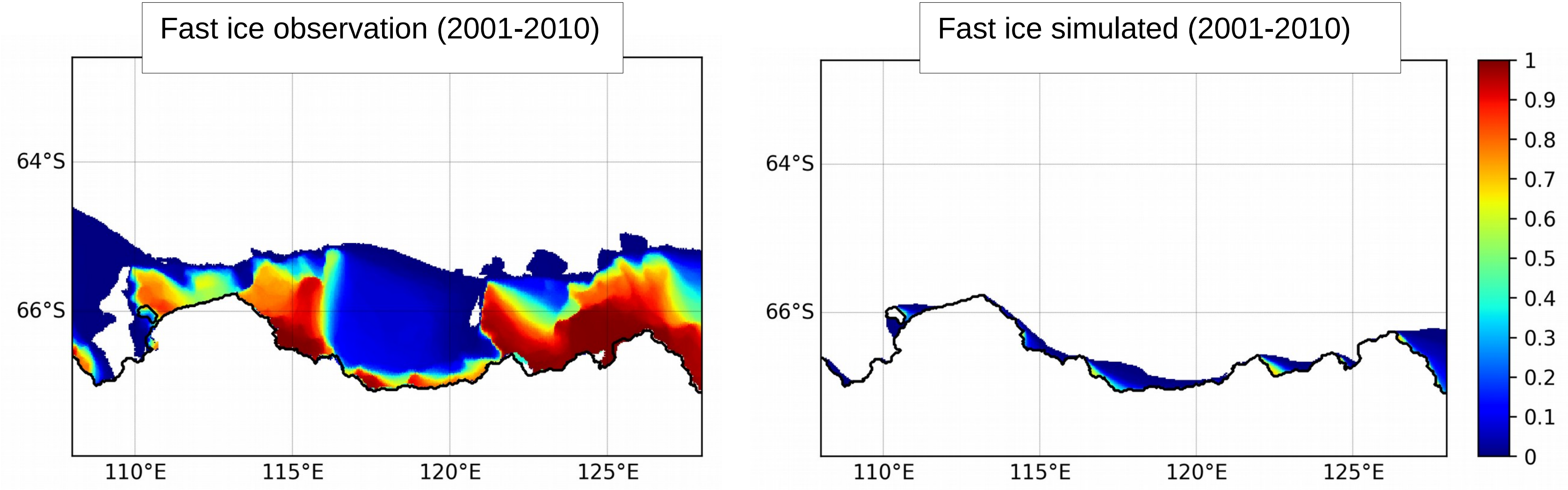
Prescribed fast ice :

- In some regional model, fast ice is prescribed by imposing a constant sea ice thickness over a certain region or by setting the sea ice velocity at zero to render the blocking effect of sea ice advection by grounded icebergs (Kusahara et al., 2016)

In this presentation

Better understanding the formation of fast ice and its link with the grounded icebergs is required to build meaningful simulation in East Antarctica with a high resolution model.

Without any fast ice parameterisation, the simulated fast ice is strongly underestimated.



Fast ice observed (left, Fraser et al., 2020) and simulated (rigth) **without** fast ice parameterisation (Van Achter et al., under review).

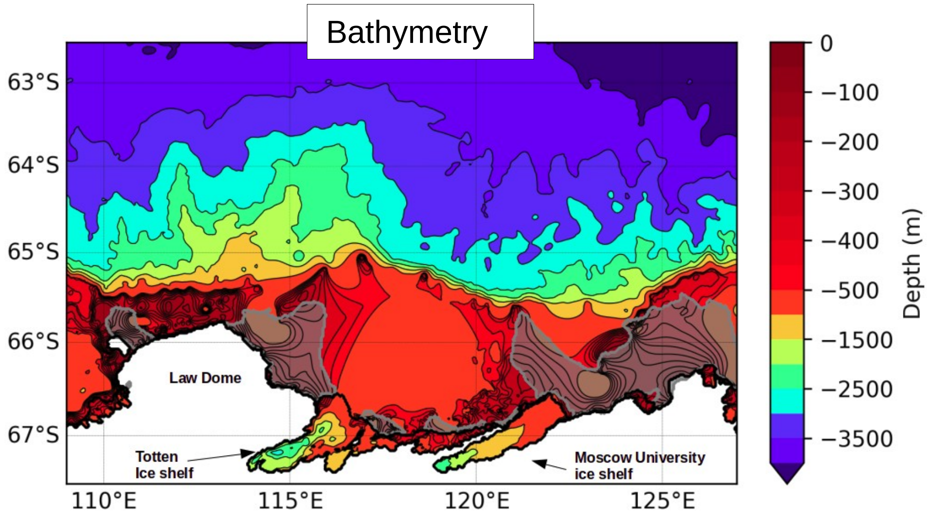
This presentation combines a grounded icebergs representation with the sea ice tensile strength parameterisation to simulate fast ice in the Totten region.

Our model design

NEMOv3.6 (OPA+LIM3) (Madec & NEMO-Team, 2016)

Regional configuration Totten24 (East Antarctica) :

- 1/24° refined ORCA grid
- Z coordinate, 75 levels
- Ice-shelf cavities with interactive melt (Mathiot et al., 2017)
- The tides are activated
- Bathymetry and ice draft are from Bedmachine (Morlighem et al., 2020)
- Atmospheric forcing is ERA5 (Hersbach et al., 2020)
- Lateral boundaries are GLORYS12v1 (Bourdalle, 2012)
- 1999-2000 spin-up, then 2001-2010 are analysed
- NEMO and LIM time steps are 150s and 900s, respectively.



Model bathymetry and domain. Ice shelf cavities are surrounded by a thick black line. The 0,75 landfast sea ice observed frequency is shown by the the shaded gray areas (Fraser et al., 2020).

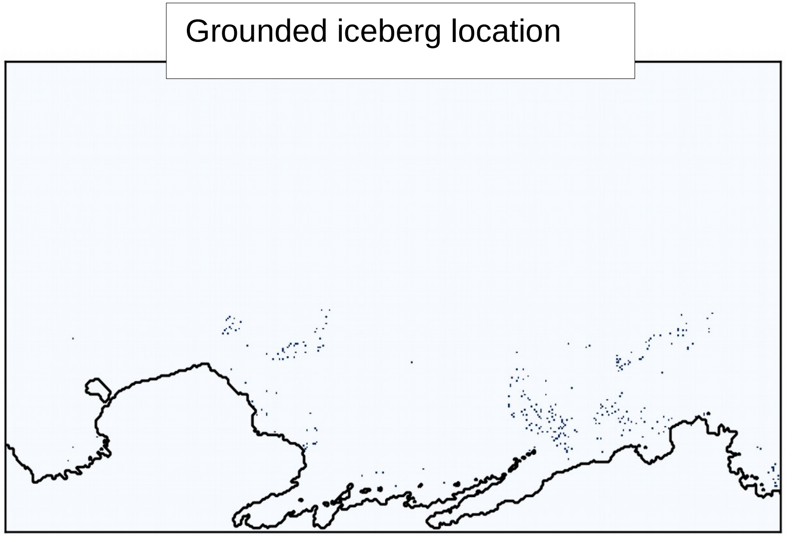
The sea ice tensile strength & grounded icebergs

The sea ice tensile strength used 2(+1) parameters :

- The eccentricity of the elliptical yield curve (rn_ecc)
- The amount of tensile strength in compression (rn_kt)
- The number of subcycling iteration of the EVP scheme (nn_nevp)

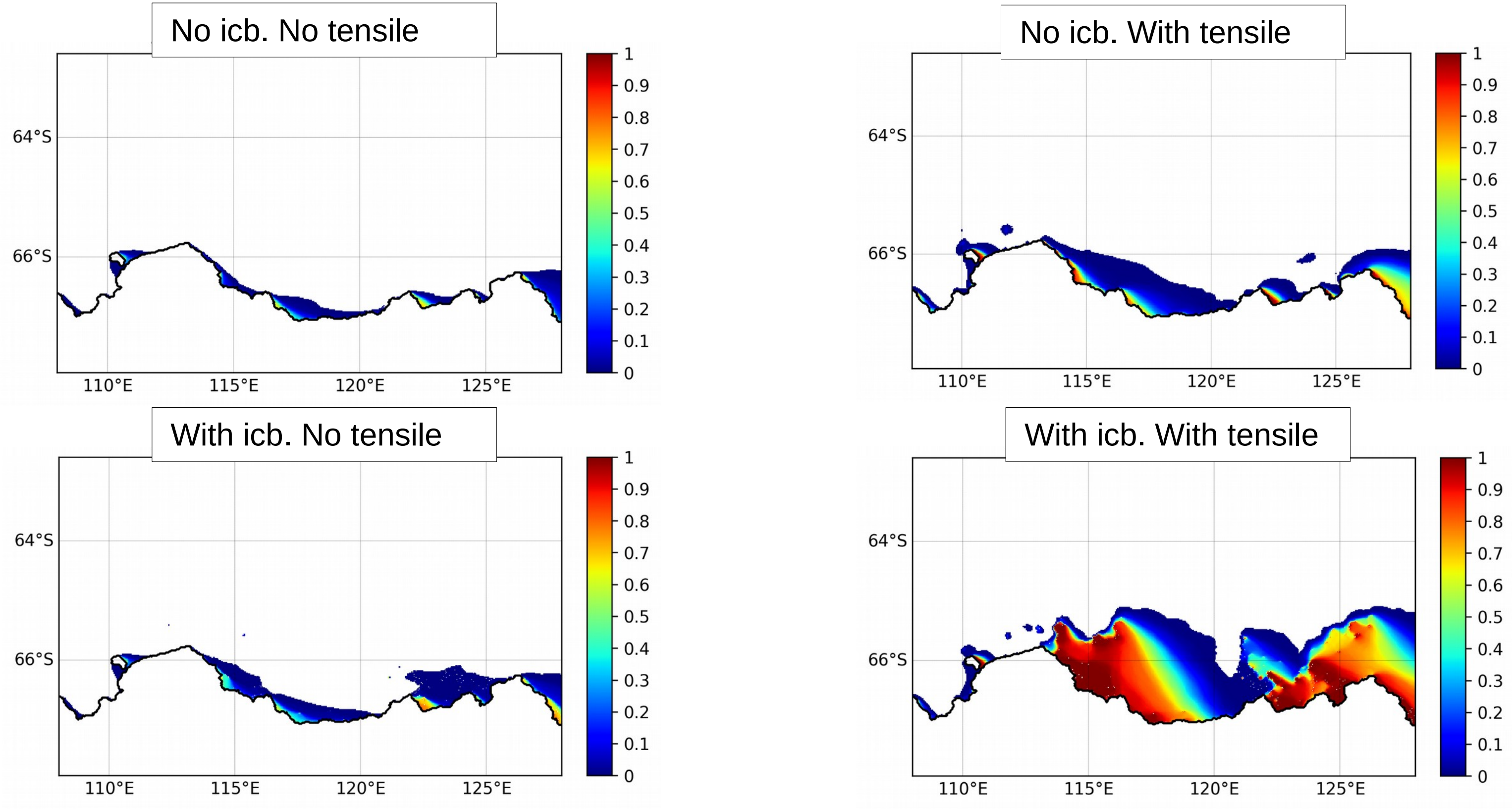
The grounded icebergs representation :

- Bathymetry set to zero at icebergs location
- Dataset [September-October 1997] extracted from the remote sensed mosaic ‘RAMP AMM-1 SAR Image Mosaic of Antarctica, Version 2’ (Jezek et al., 2013)
- Icebergs location are filtered to avoid icebergs wall
- Icebergs location is static for the entire run



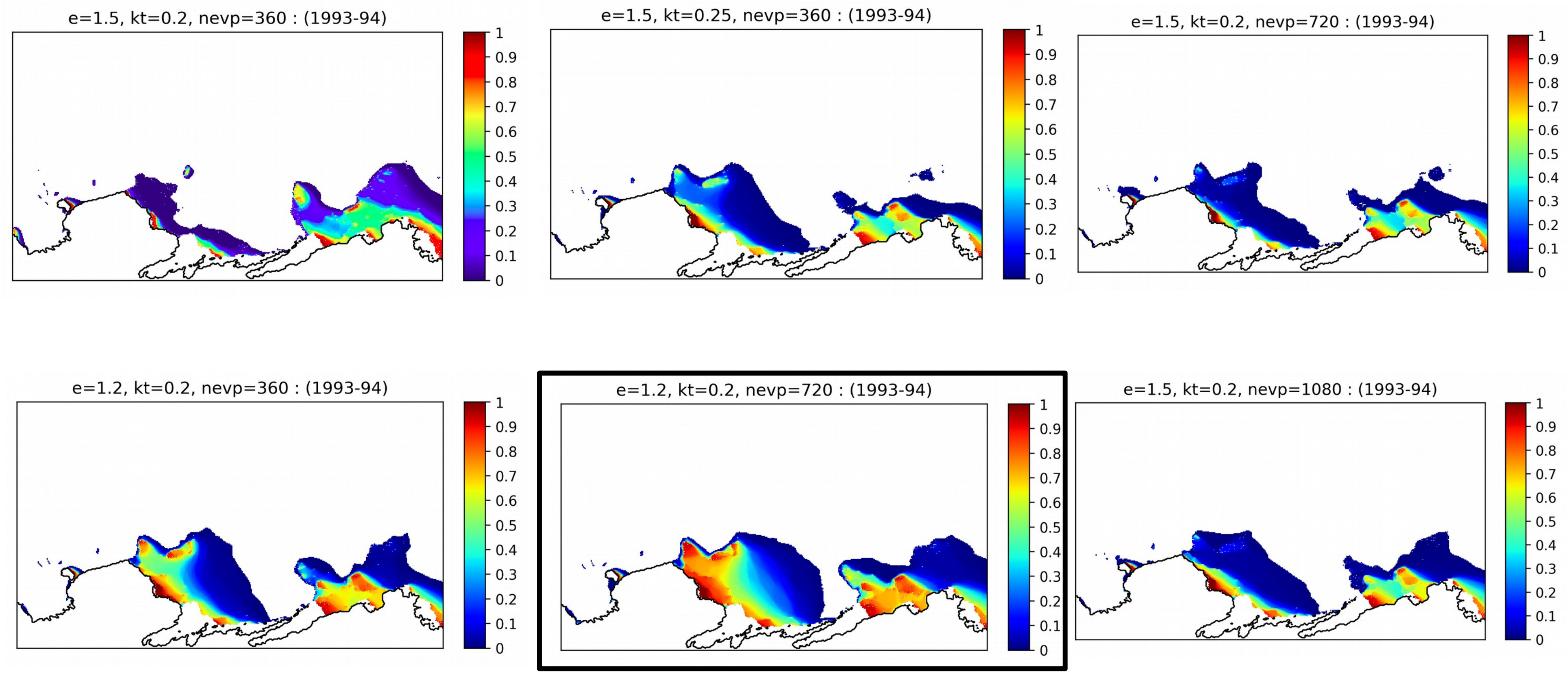
Fast ice simulated only when icebergs and tensile strength are combined

Fast ice frequency (2001-2010)

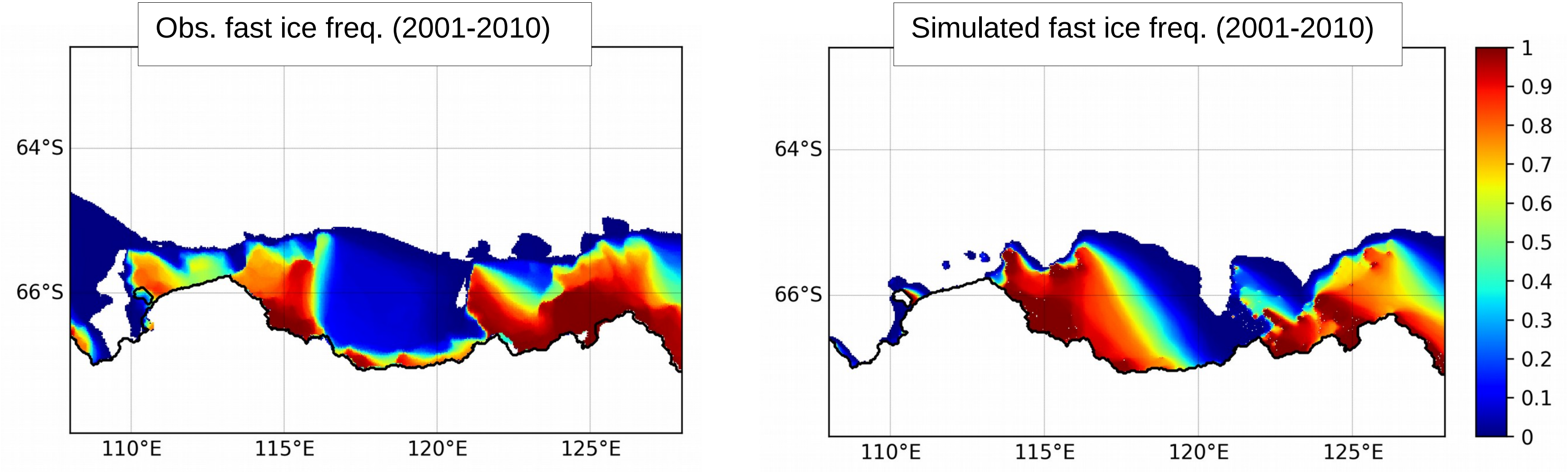


Parameters selection

Fast ice frequency (1993-1994)



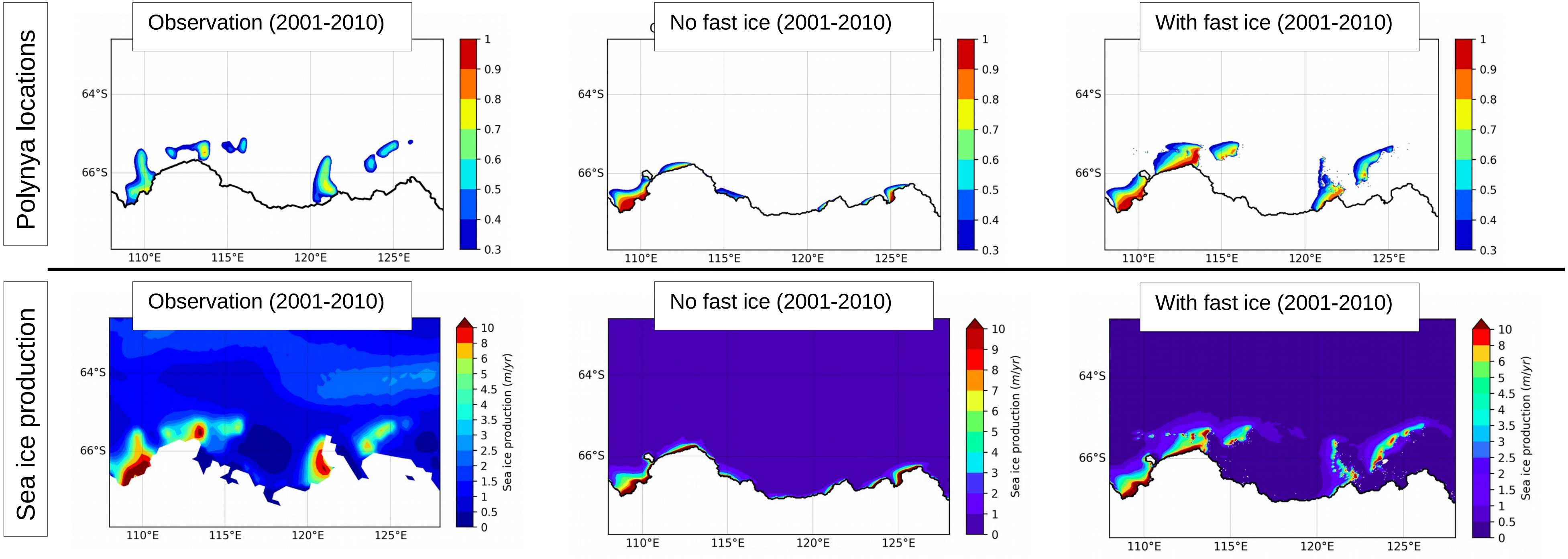
Fast ice simulated by tensile + grounded icebergs



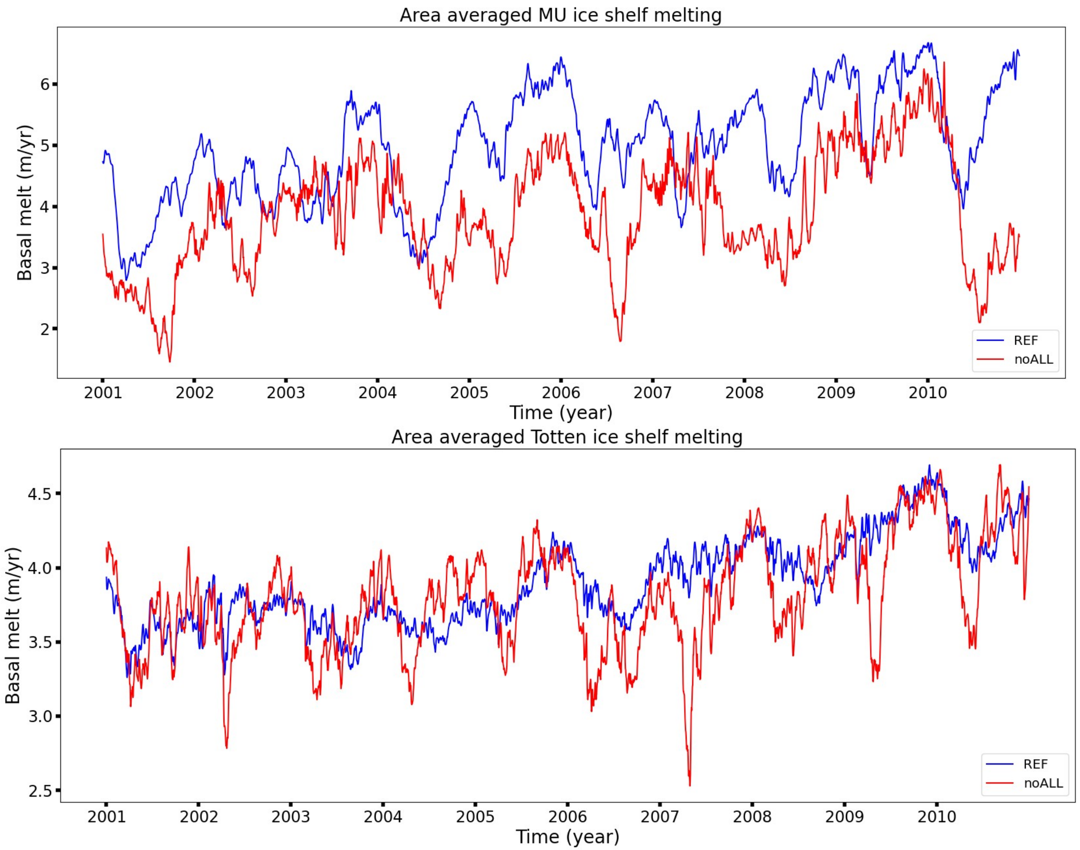
Fast ice observed (left, Fraser et al., 2020) and simulated (rigth) **with** fast ice parameterisation (Van Achter et al., under review).

Fast ice simulated by tensile + grounded icebergs

Better fast ice representation improves both polynya location and sea ice production :



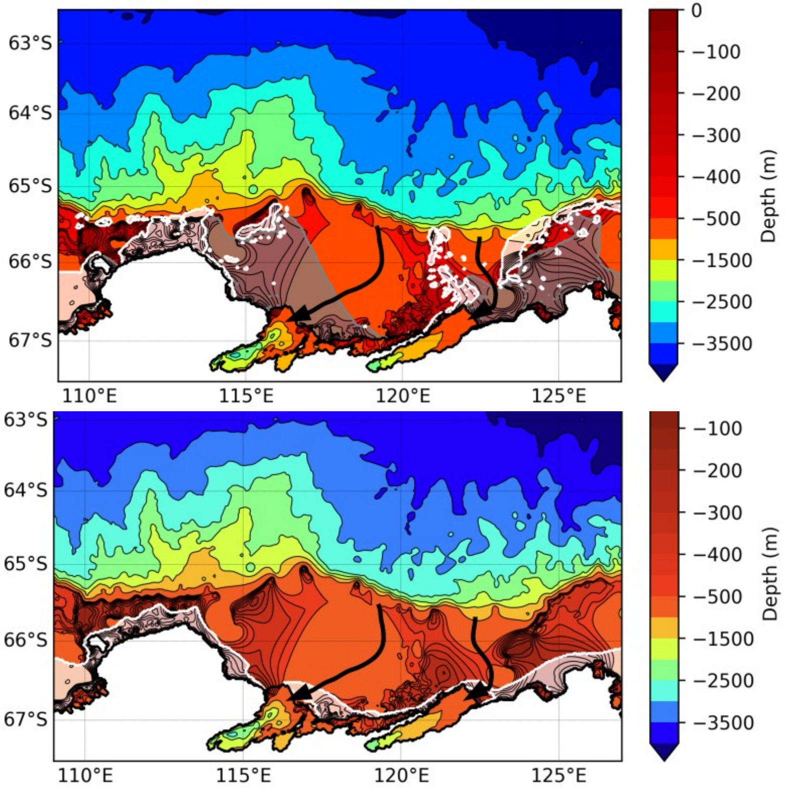
Ice shelf melt sensitivity to fast ice



Area-averaged basal melt for Moscow University (top) and Totten (bottom) ice shelf, with (blue) and without (red) fast ice parameterisation.

Landfast sea ice affects ice shelf cavities in different ways, either by increasing the ice melt (+28% for MU ice shelf) or by reducing its seasonal cycle (+10% in March-May for Totten ice shelf)

Ice shelf melt sensitivity to fast ice



Landfast sea ice (gray shaded area) and sea ice production zones (white contour) are shown for the simulation **with** (top) and **without** (bottom) fast ice. Black arrows depict the mean mCDW pathways for both cavities.

The presence of fast ice favours the intrusion of warm water into both Totten and Moscow University cavities.

Moscow University is mostly impacted by the fast ice through the displacement of the sea ice production zones from coastal to offshore areas. With less sea ice production and more sea ice melt, the ocean in front of the cavity is more stratified, which favors warm water intrusion all year long

For the Totten cavity, the presence of fast ice prevents a sudden decrease of basal melt at the end of summer thus weakening the melt seasonality. Through a decrease in sea ice production near the coast and a modification in the AcoC transport, the fast ice reduces the amount of cold water mixing with the mCDW, and therefore increases the melt.

Conclusion

- Realistic simulation of landfast sea ice is made possible with the combination of grounded icebergs and the tensile strength parameterisation.
- Realistic fast ice extent improves the simulated polynya location and the simulated sea ice production.
- Landfast sea ice increases the basal melt of the ice shelf cavities but this increase is highly dependant on the bathymetry (path of the mCDW to the cavity) and on the relocation of the sea ice production zone.
- Further developements should be considered :
  - Dynamical icebergs instead of prescribing fixed location
  - Year-to-year evolving iceberg location dataset (for better interannual fast ice variability)

Conclusion

All these results are part of a study that has been submitted recently :

van achter et al., 2021:Modelling landfast sea ice and its influence on ocean-ice interactions in the area of the Totten Glacier, East Antarctica