The role of bathymetry in the local circulation and cross-shelf heat transport in the Denman region of Antarctica

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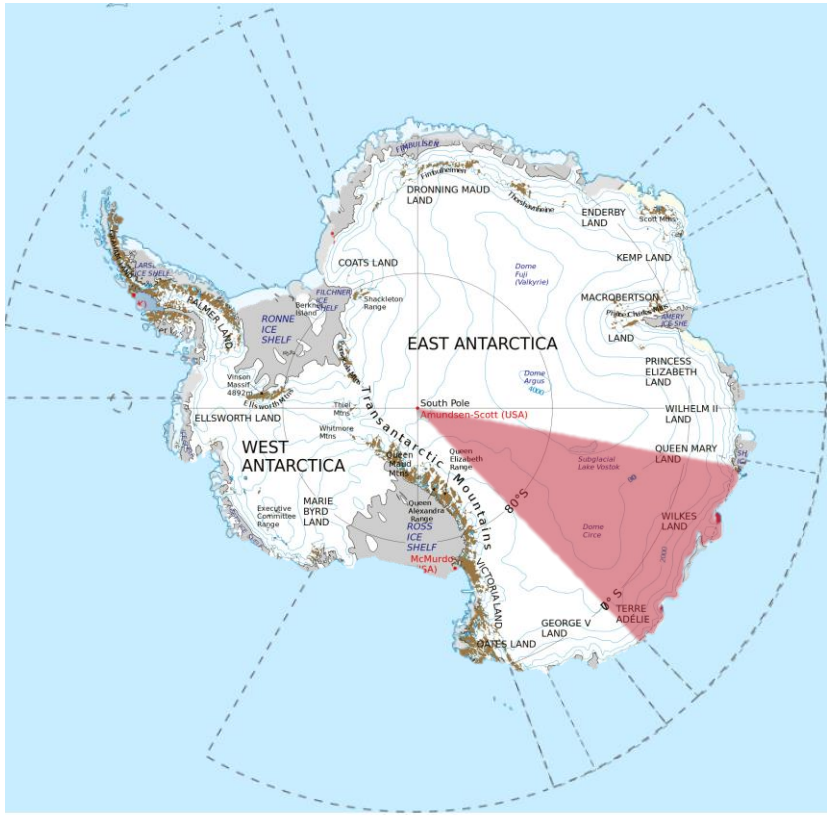
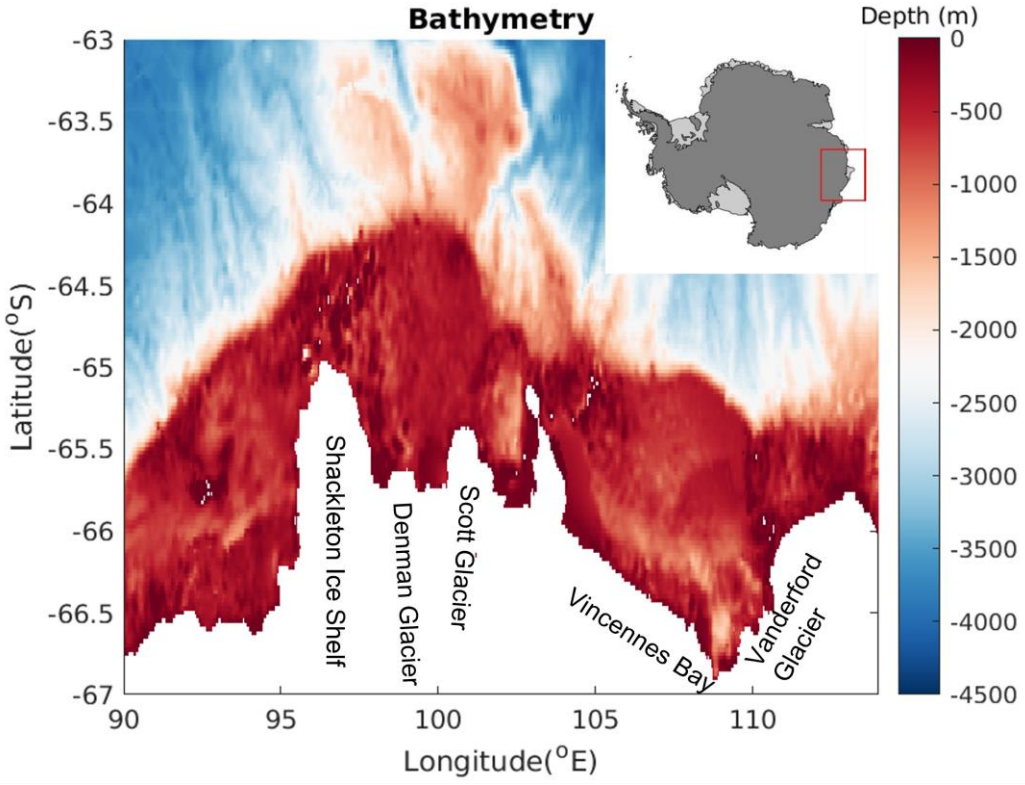
Denman region and recent changes

- Antarctica ice sheet = **58 m** global sea level rise (Fretwell et al., 2013).

  East Antarctica = **53 m** global sea level rise (Fretwell et al., 2013).
- Wilkes Land sector contributing up to 20% of the total Antarctic mass loss over the last four decades (Rignot et al., 2019).
- Denman glacier is the **2nd** largest sea-level contributor in the East Antarctica (Miles et al. 2021).





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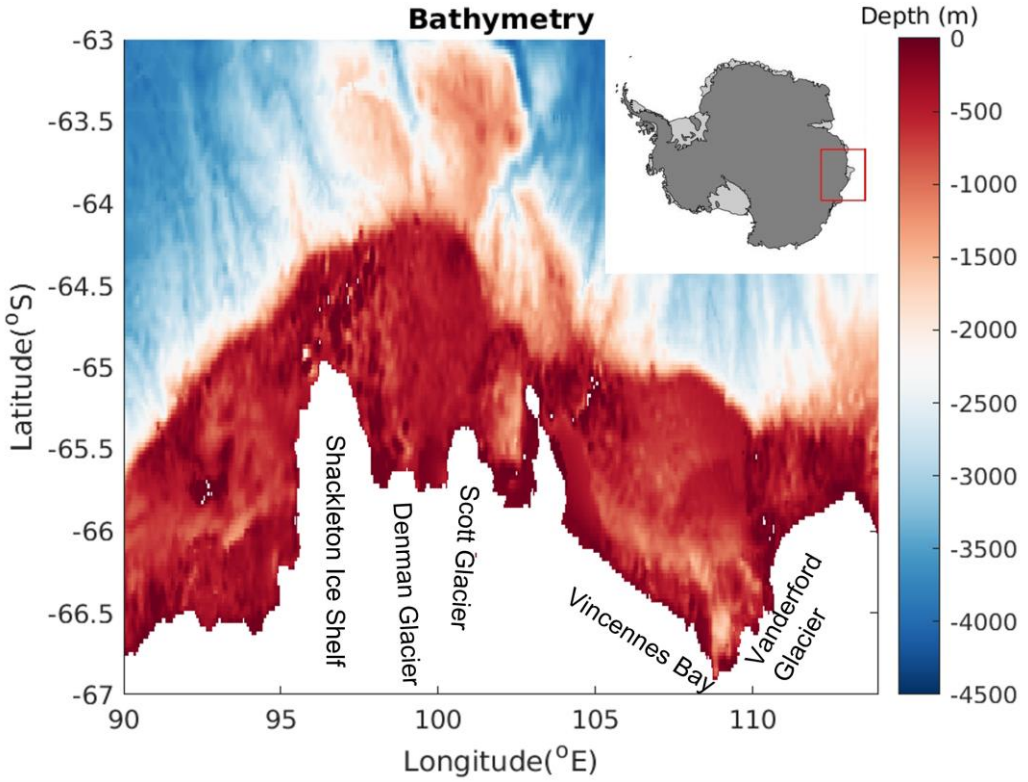
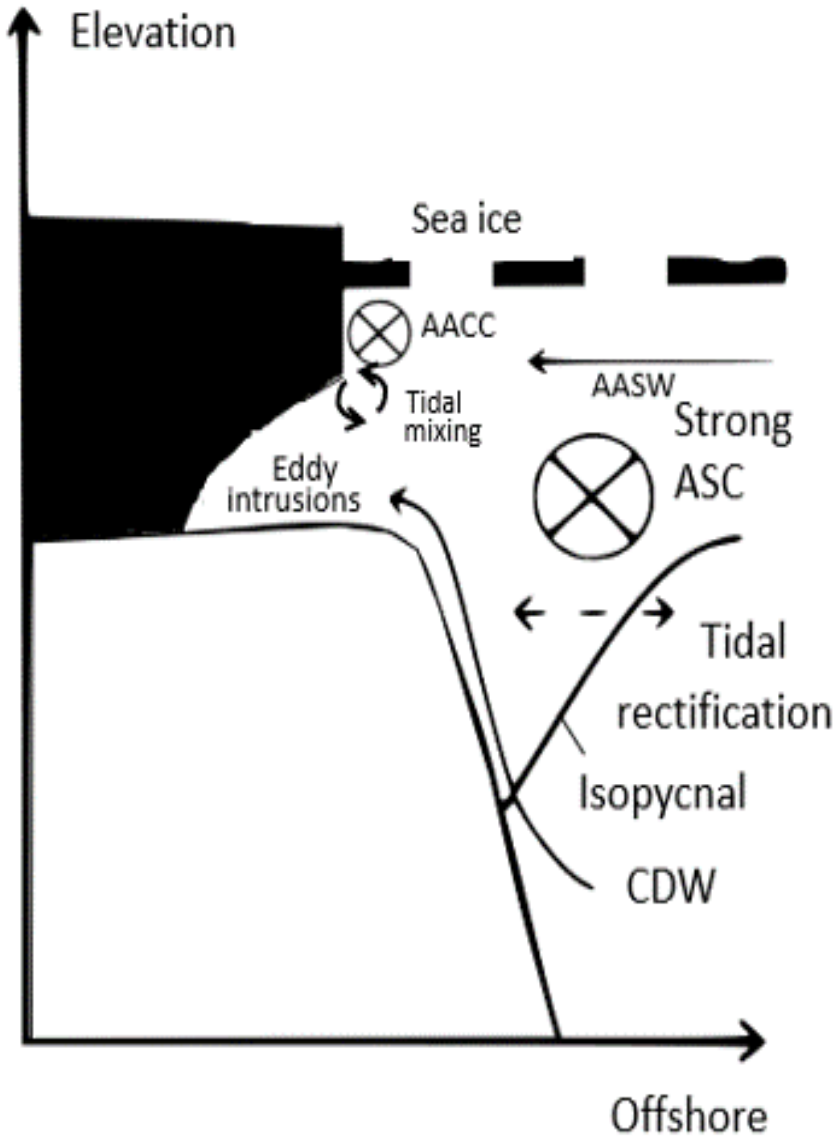
Recent changes:

- The acceleration of the Denman system is evident in both its grounded (17 ± 4% acceleration) and floating (36 ± 5% acceleration) components (Miles et al., 2021).



Possible reasons for the ice mass loss



Possible reasons: **basal melt**, iceberg calving, surface melting

(Dinniman et al., 2016)

SO —heat→ ACC —heat→ **ASC** —heat→ **Continental shelf** —heat→ 

Thompson et al. (2018)

Fresh shelf | Dense shelf | Warm shelf

Three main ocean processes:

- **mean circulation**
- **eddies**
- tides

Potential role of the bathymetry

Bathymetry has a potential to change the ocean circulation.

Continental slope

- shape of the continental shelf → location of the currents
- submarine canyons → drive cross-shelf exchange

Continental shelf

- troughs
- depressions

→ **facilitate** warm waters access

- bathymetric highs
- seabed ridges

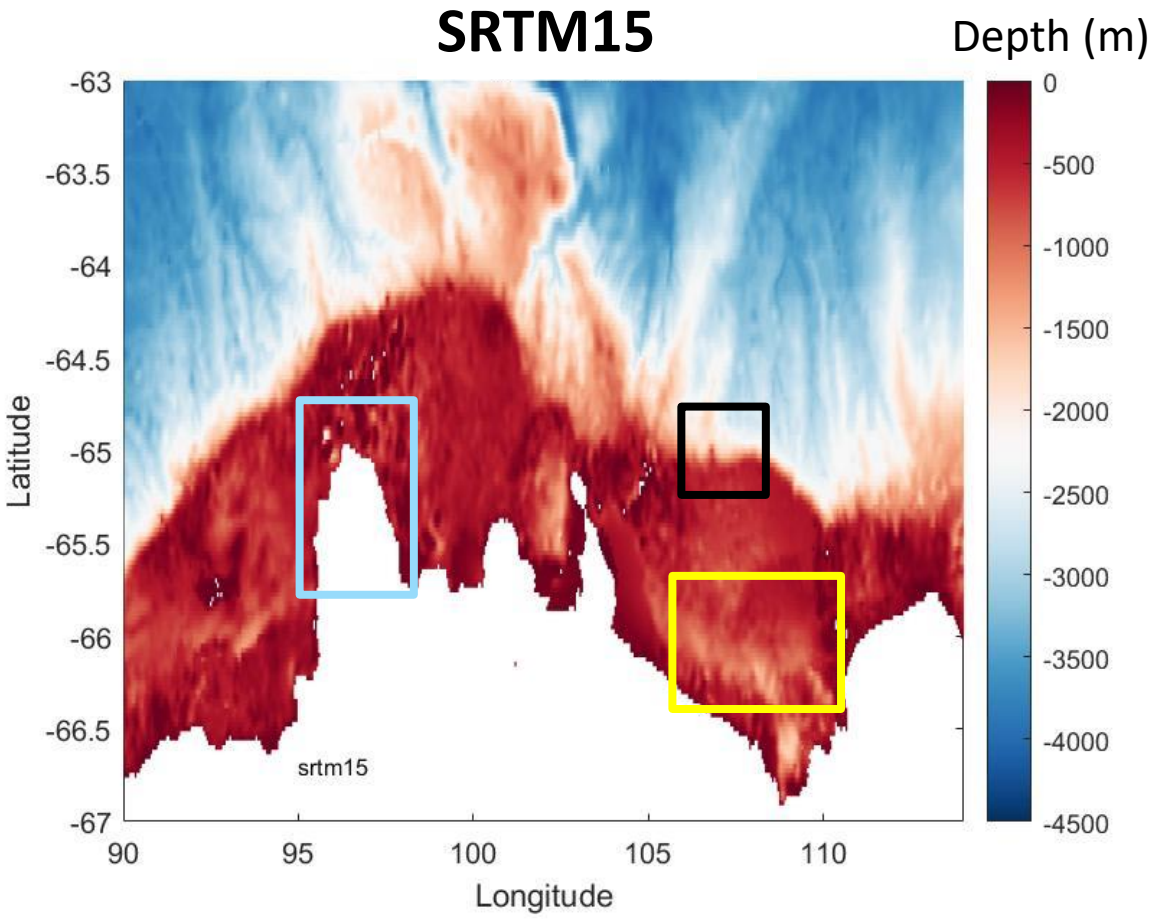
→ **obstruct** warm waters progress

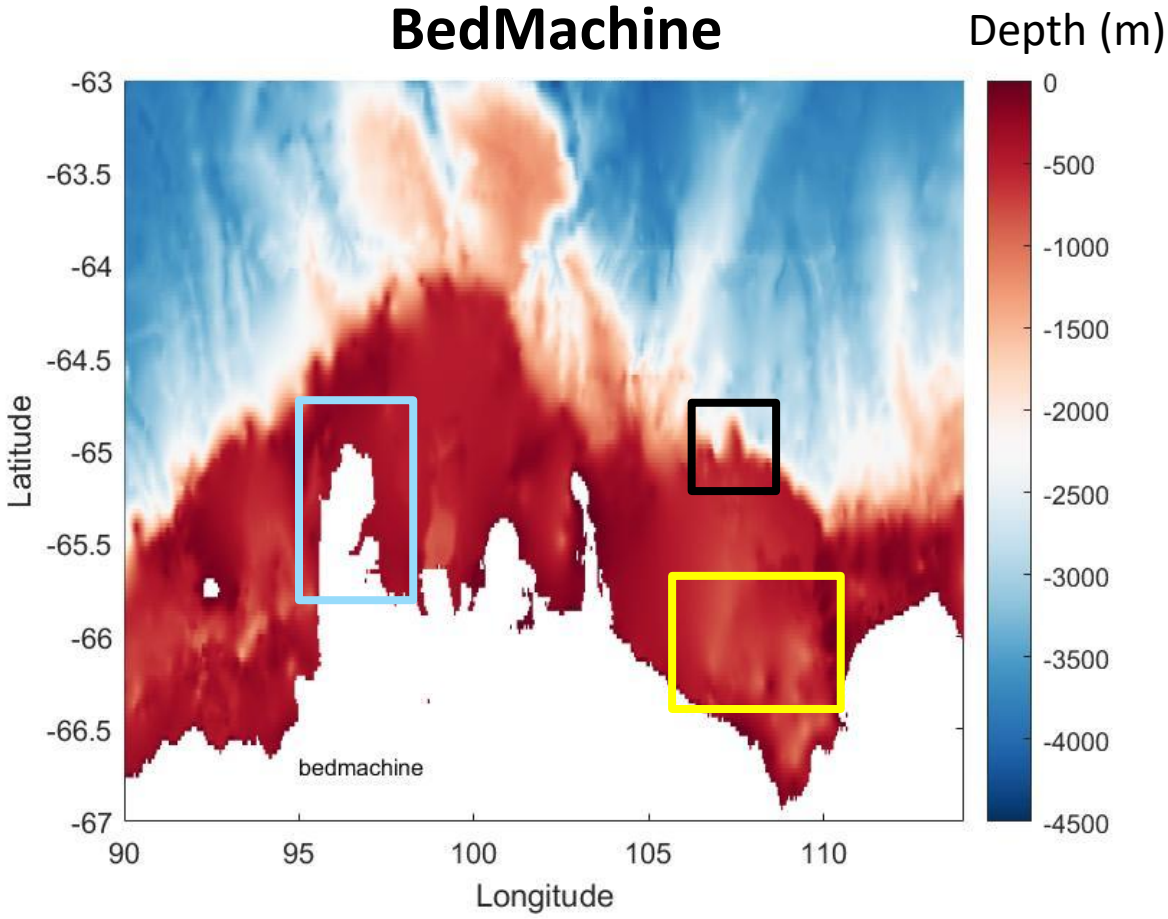
→ increase seafloor roughness

→ **Heat transport**

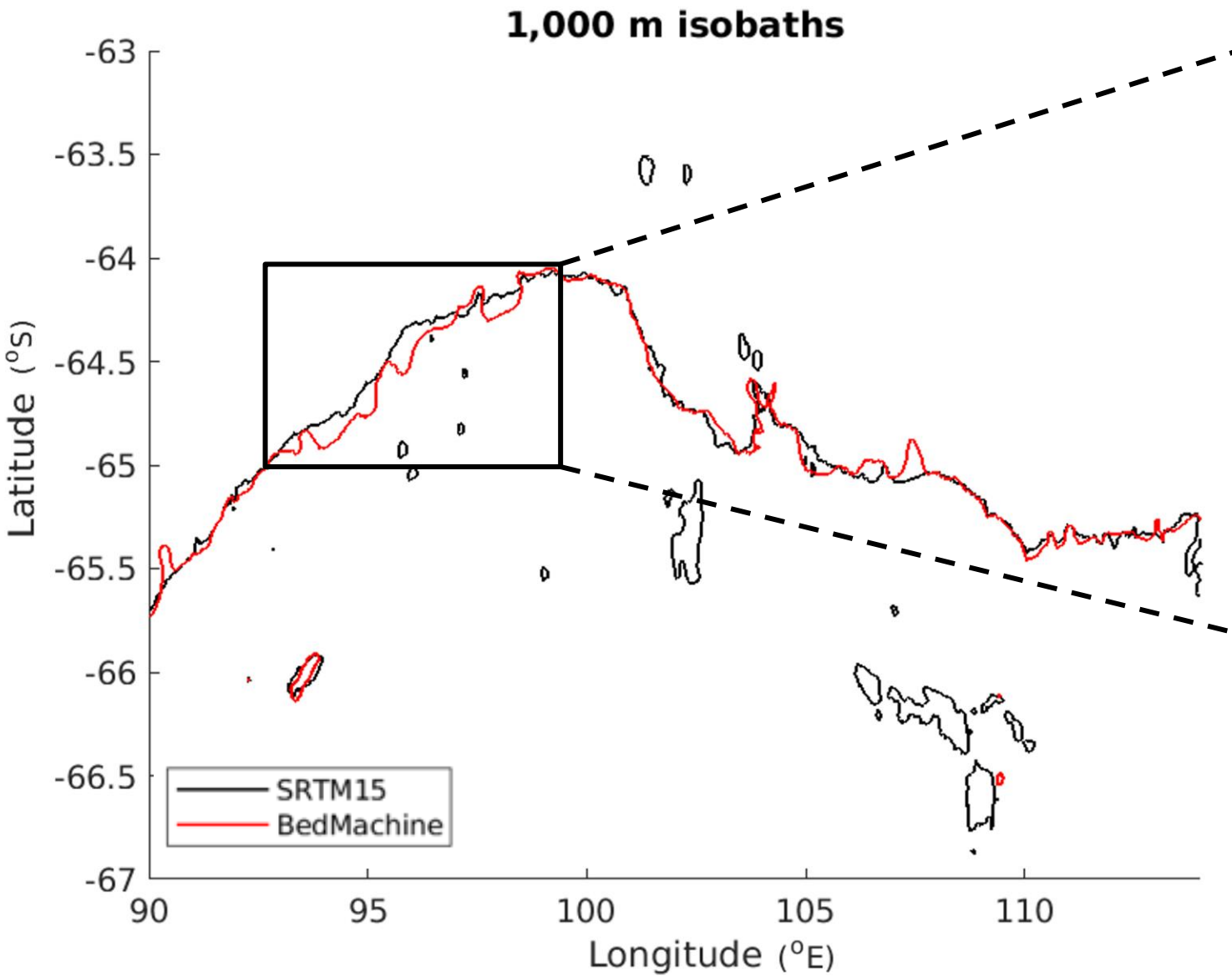
Bathymetry

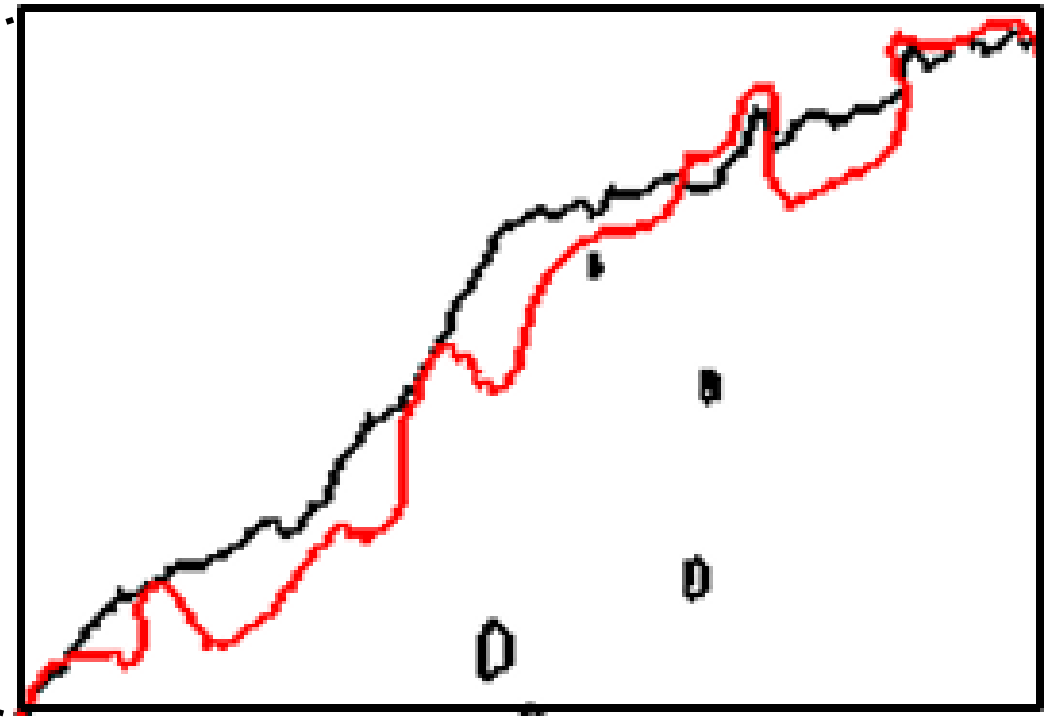
- Available datasets: **SRTM, BedMachine Antarctica,** ETOPO, IBCSO
- Differences: ice shelf boundary, seafloor roughness, topographic features





Bathymetry





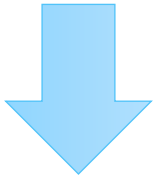
- Difference: shape of the continental shelf

Project aim and objectives

- Satellite derived bathymetry is the only data available for the Denman region

(Brancato et al., 2020; Miles et al., 2021; Liang et al., 2021).

SRTM15 **BedMachine**



high-resolution model

Estimate the impact of the bathymetry differences.

Objectives:

1. validate the regional model.
2. assess the role of uncertainty in bathymetry for the shelf circulation, properties, and cross-shelf heat exchange.

Model configuration & experiments

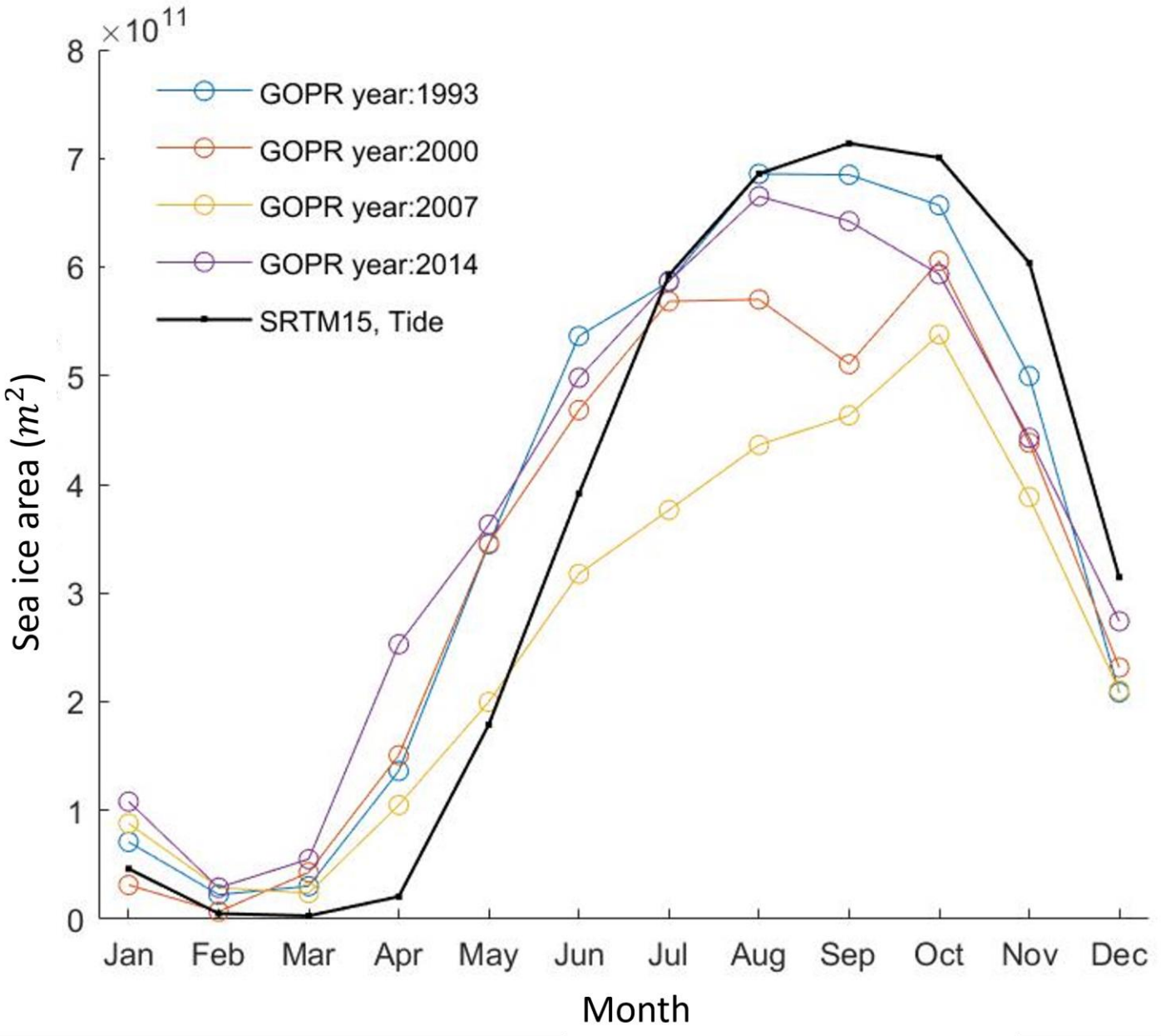
Model configuration (MITgcm):

- ❑ Resolution: 1/20° in zonal direction, 1/40° in meridional direction
- ❑ Vertical: 160 vertical levels
- ❑ Boundary condition: **ACCESS-OM2-01** global ocean model
- ❑ Repeat atmospheric forcing: JRA55v1.3 external forcing
- ❑ Tides: TPXO9v4 tides
- ❑ Bathymetry data: SRTM15_PLUS, MEaSUREs BedMachine Antarctica, Version 2

Experiments:

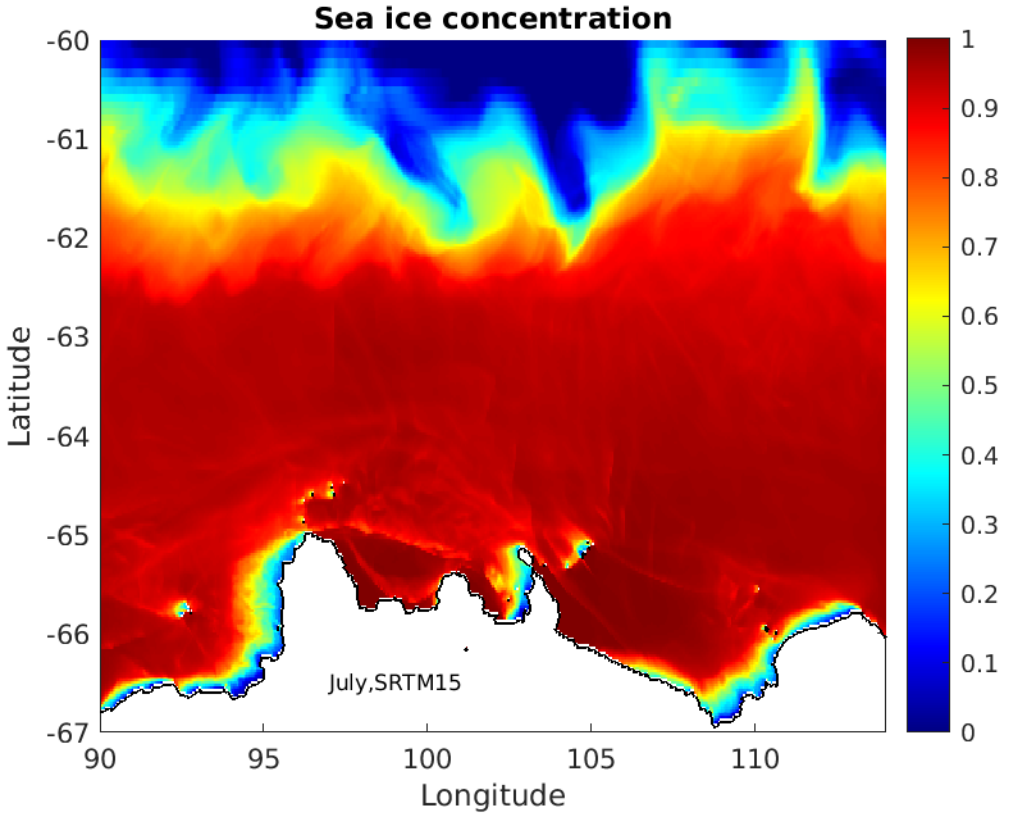
- ❑ **Bathymetry**
- ❑ Tide
- ❑ Resolution

Model validation – Sea ice area

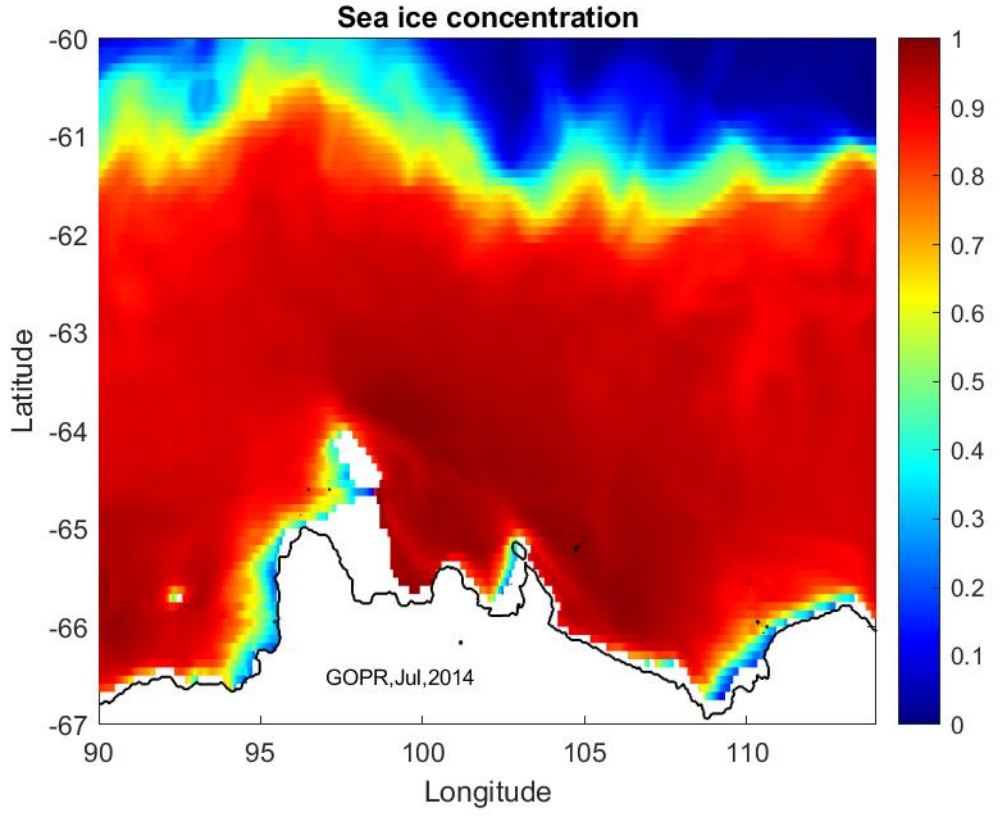


- Seasonal cycle with similar amplitude
- Timing bias: Start forming later but catch up quickly

Model validation - sea ice concentration

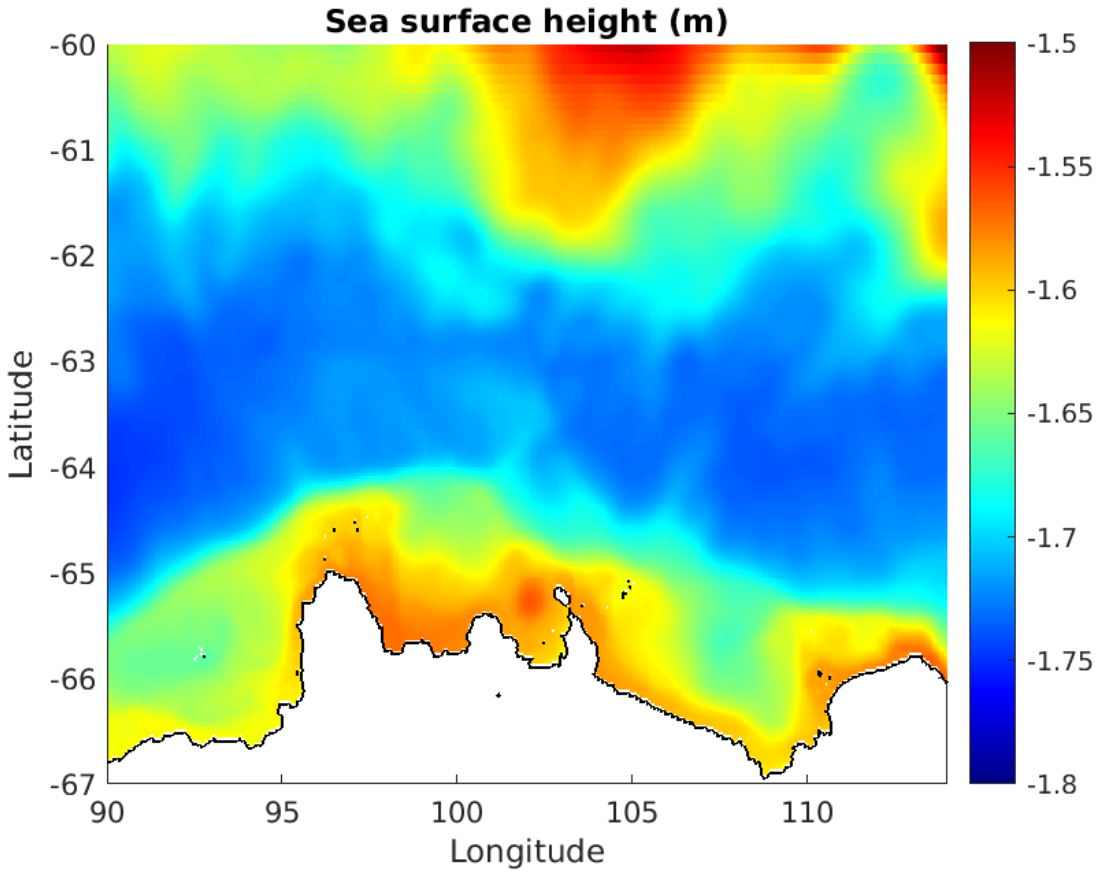


MITgcm, SRTM15

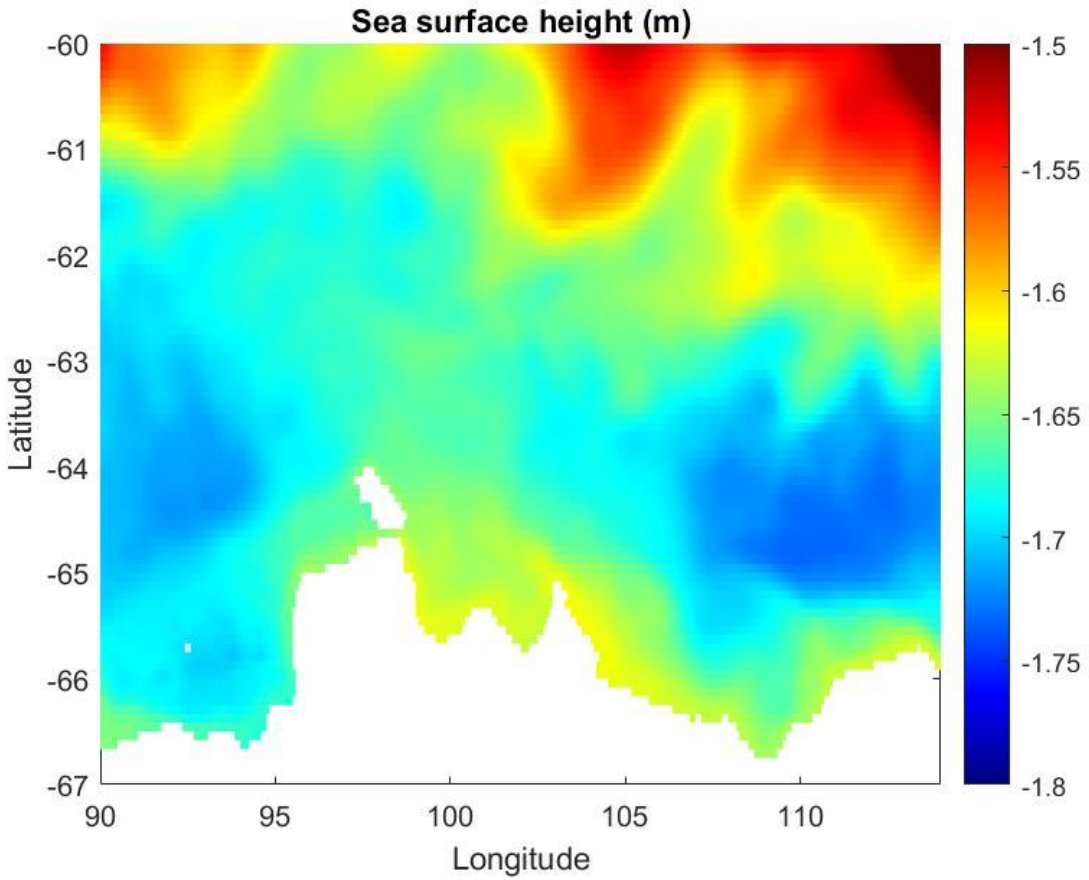


GOPR

Model validation – SSH



MITgcm: SRTM15, tide



GOPR

Model validation – SLA standard deviation

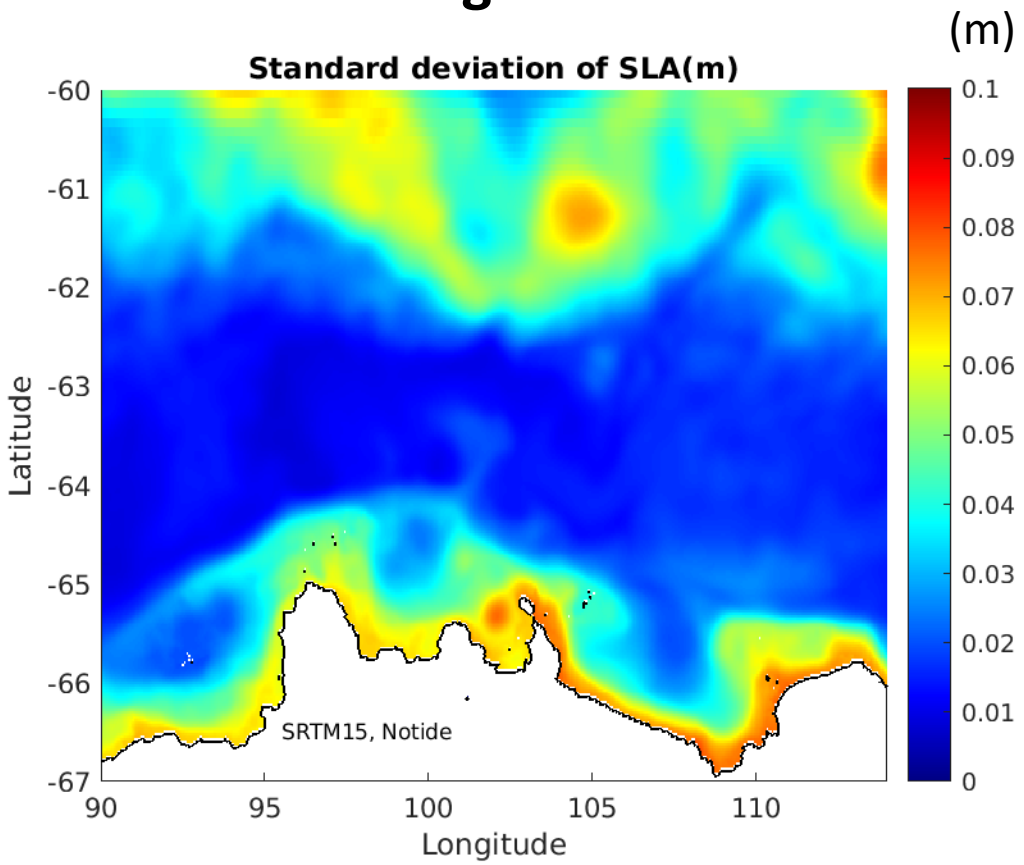
- Bias: low variabilities in the MITgcm

→ The sources of the bias: from ACCESS model, monthly-mean open boundary conditions, repeat-year atmospheric forcing

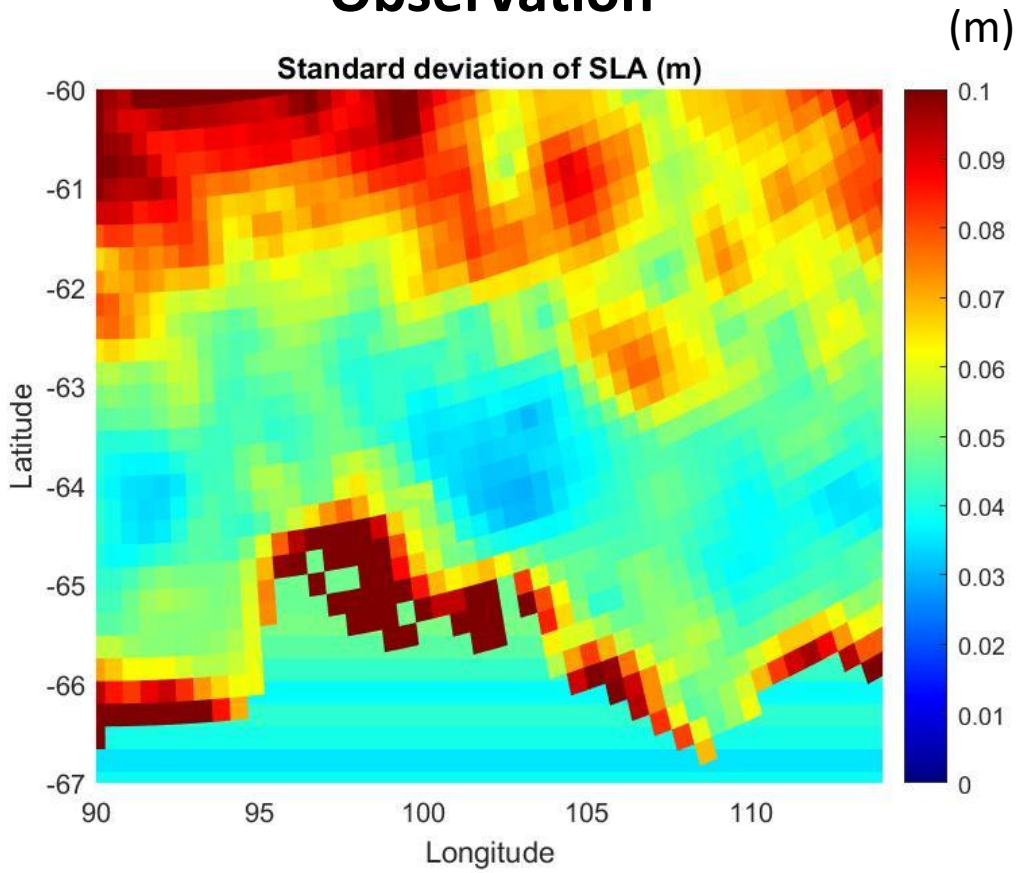
→ Standard deviation of the SLA could be very different (by a factor of 2-5)

(e.g. Kiss et al.,2020; Farneti et al., 2010; Miles et al., 2014).

MITgcm

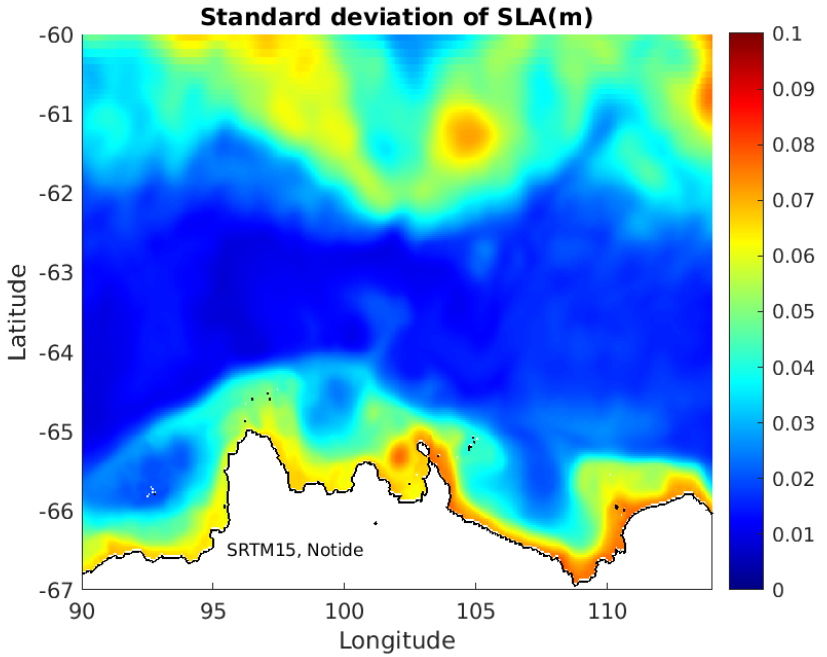


Observation

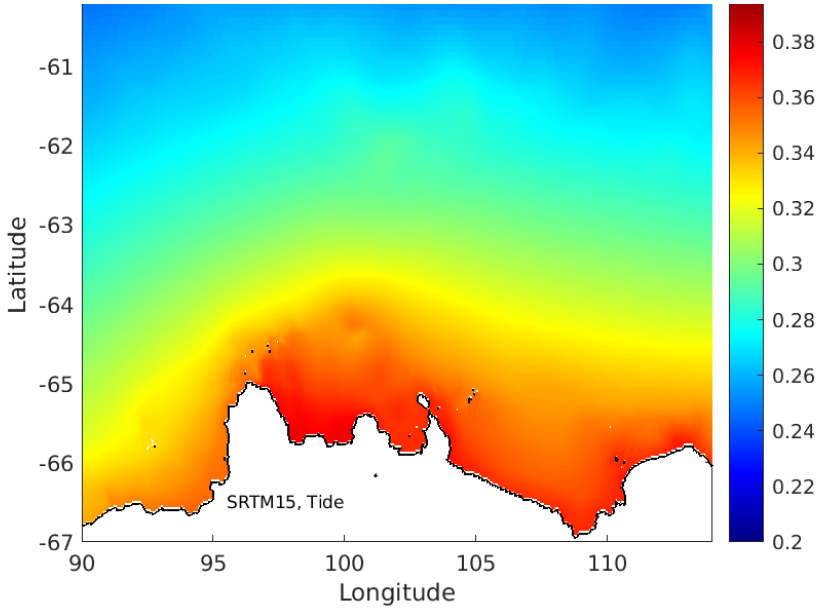


Model validation – SLA standard deviation

MITgcm
SRTM15
No tide



MITgcm
SRTM15
tide



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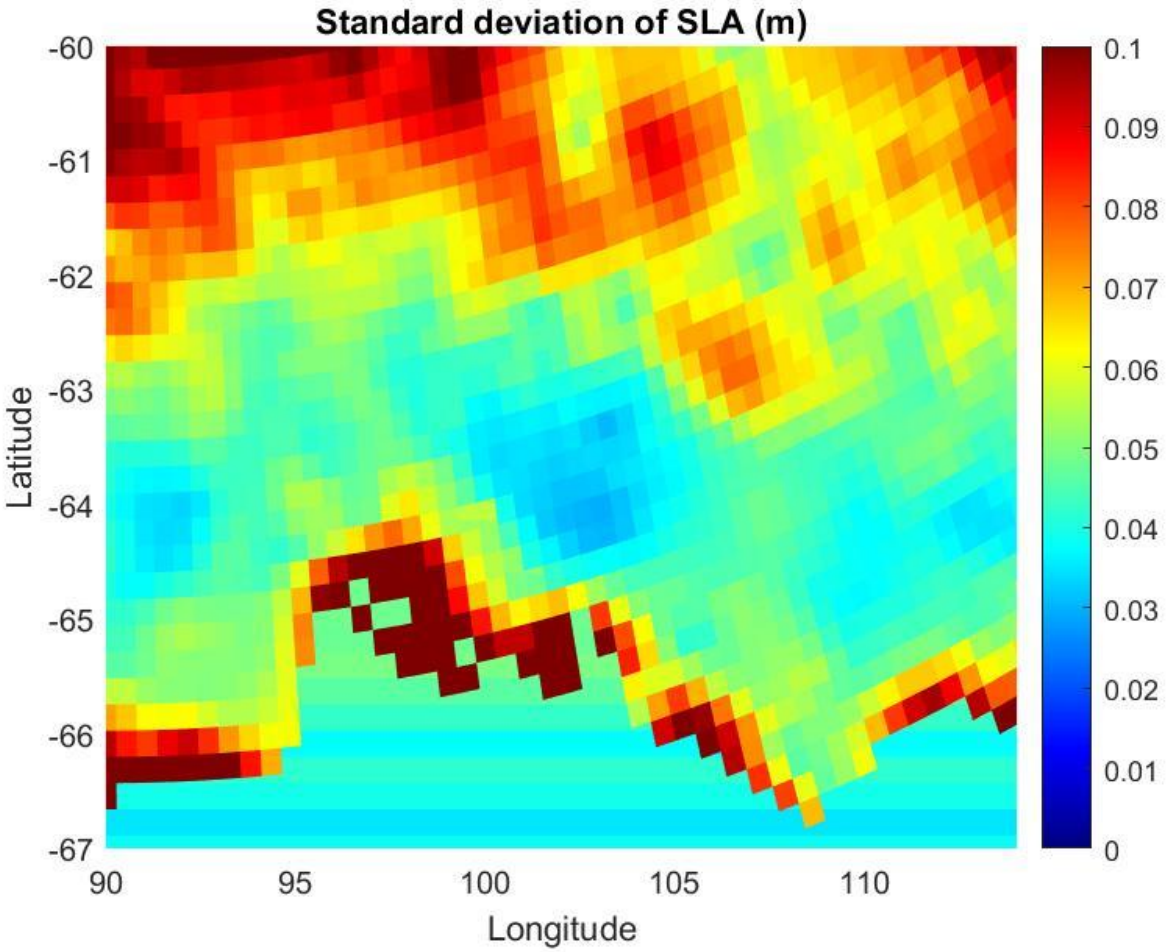
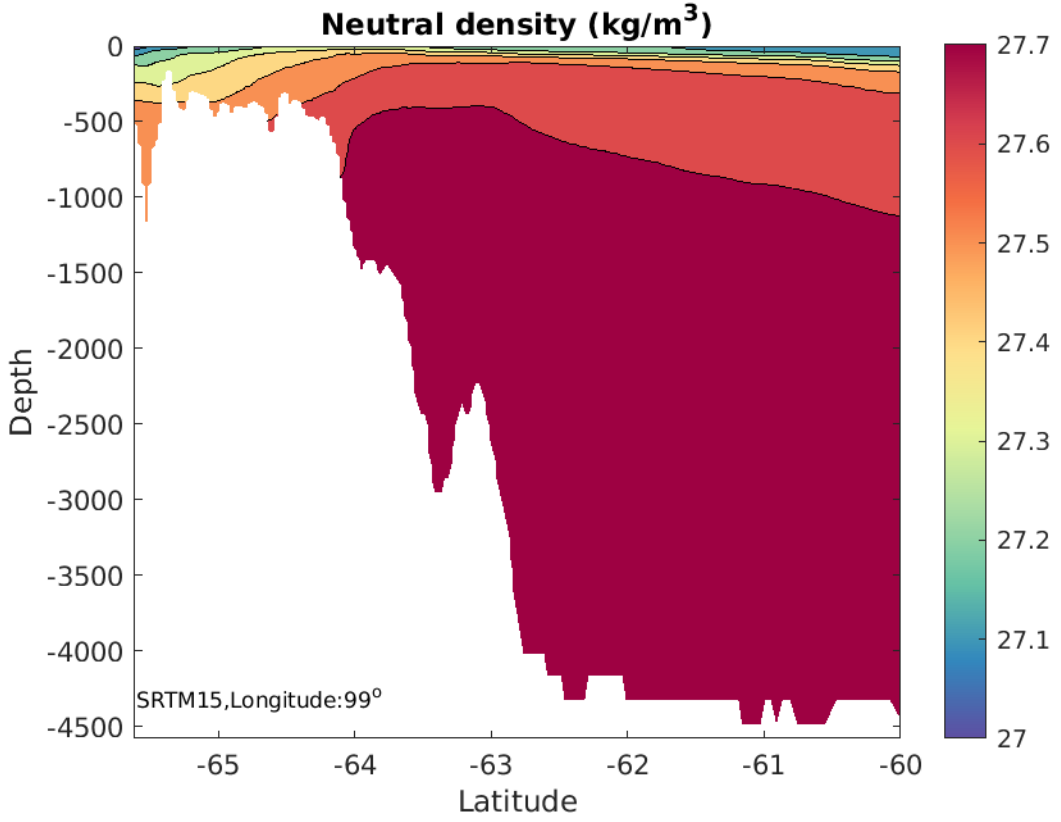
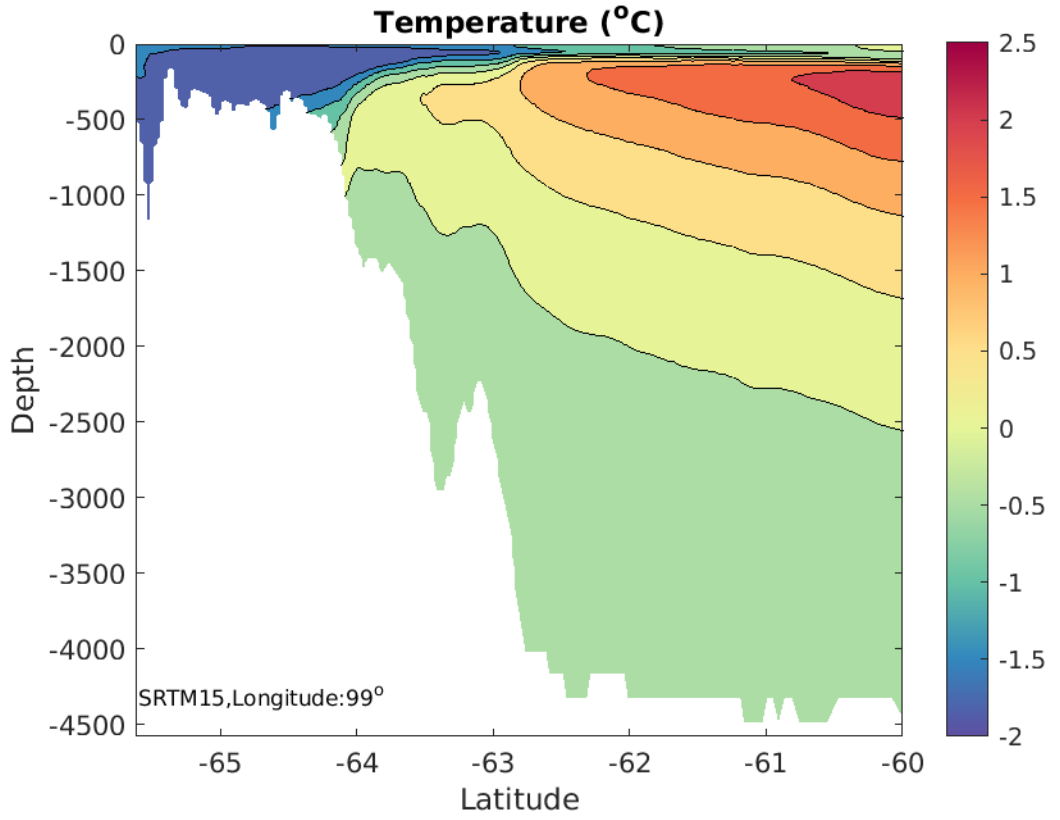


Result - Fresh shelf

- Isopycnals and isotherms intersect with the continental slope
  → eliminate the direct pathway for CDW onto the continental shelf
  → little or no dense shelf water flows across the shelf break (Thompson et al., 2018).





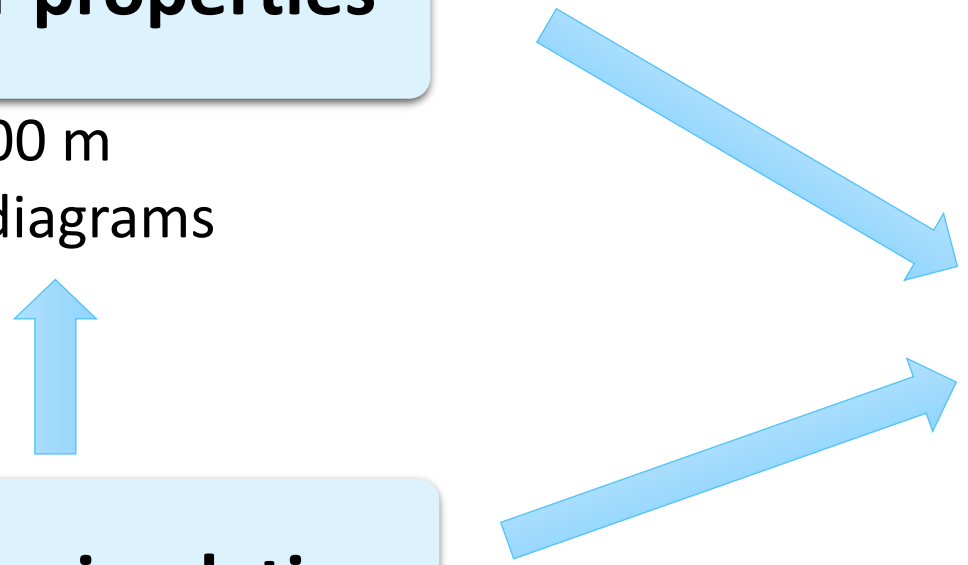
Diagnostics

Water properties

- T 400 m
- TS diagrams

Ocean circulation

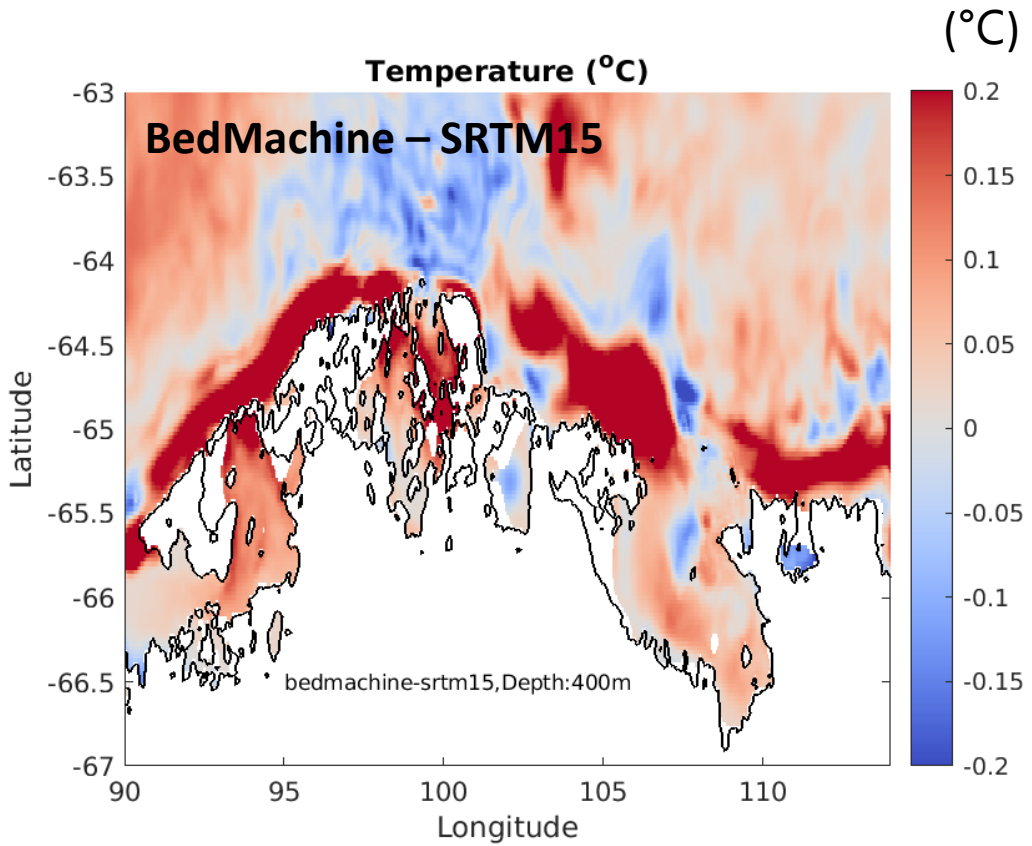
- MKE
- Stream function
- EKE

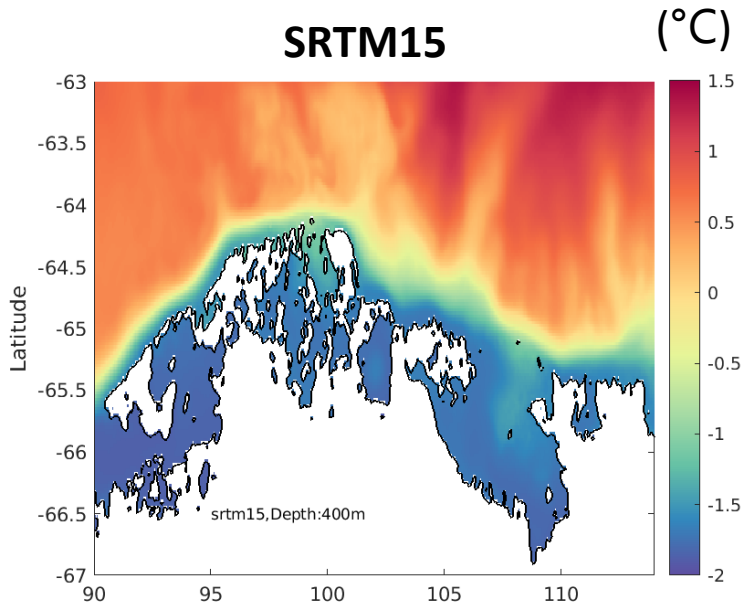


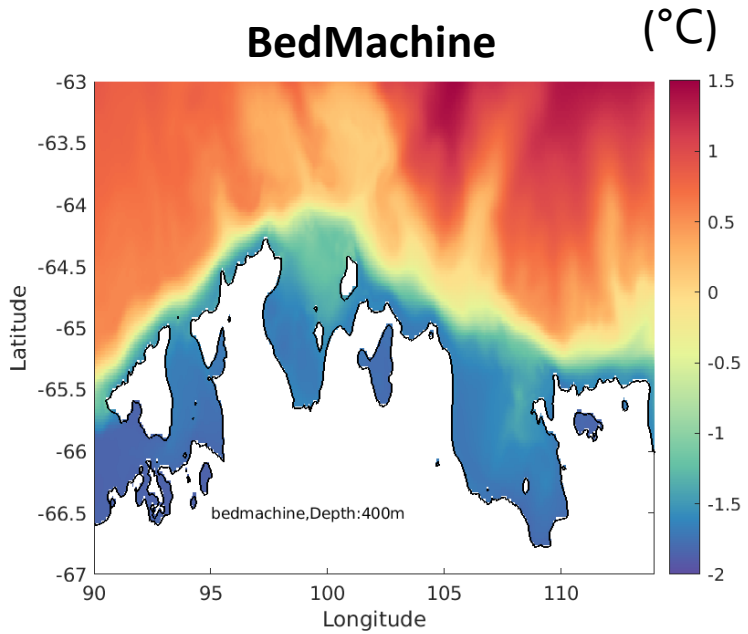
Heat flux

Water properties – T 400 m

- Continental slope (up to 0.9°C higher in BedMachine)
  → change in ASC: meridional shift, intensification
- Inner shelf (up to 0.1°C higher in BedMachine)
  → small-scale topographic features



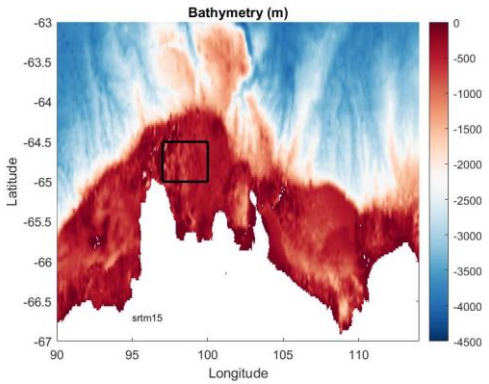


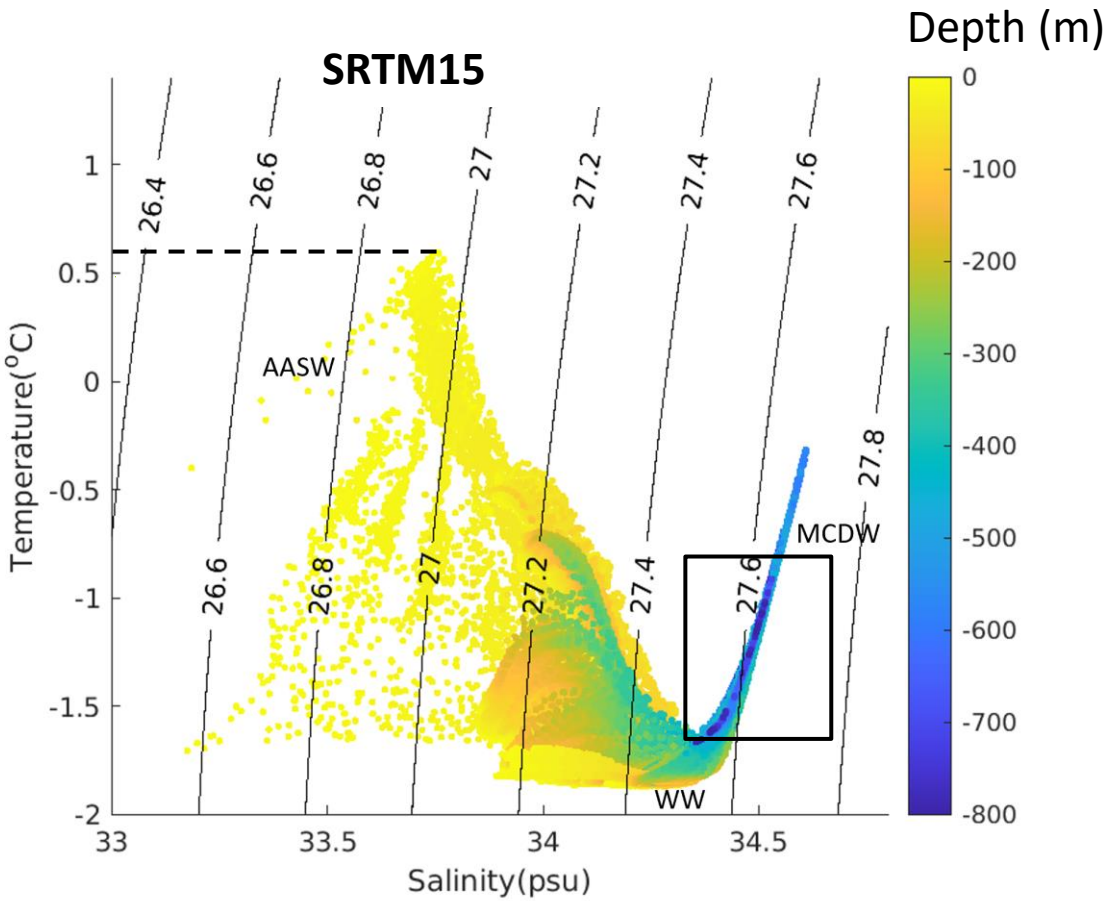


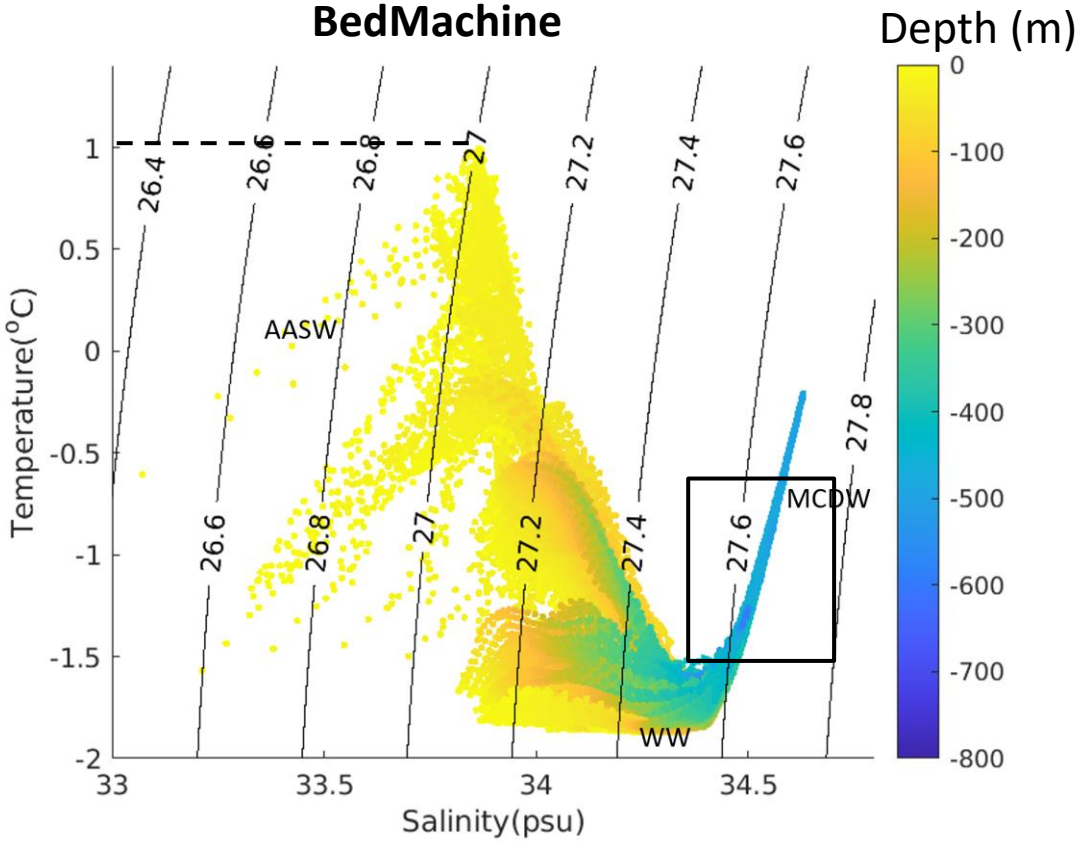
Water properties – TS depth

- About 0.5°C higher temperature of AASW in BedMachine.
- Deeper MCDW in SRTM15

→ deeper troughs and depressions on the continental shelf of SRTM15







Water properties – TS volume

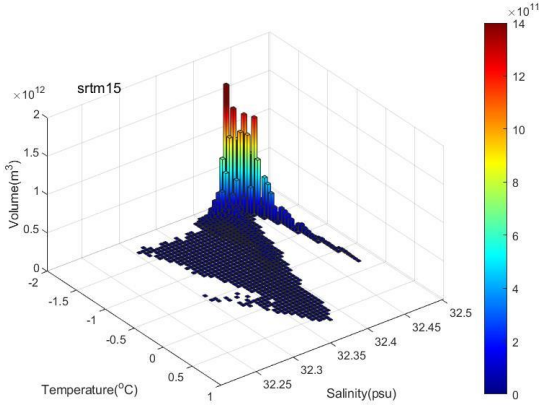
- The largest volumes per T/S bin are seen within the WW range.

Difference:

- Higher temperature of AASW in BedMachine.
- Fresher WW in SRTM15.
- Warmer MCDW in SRTM15.

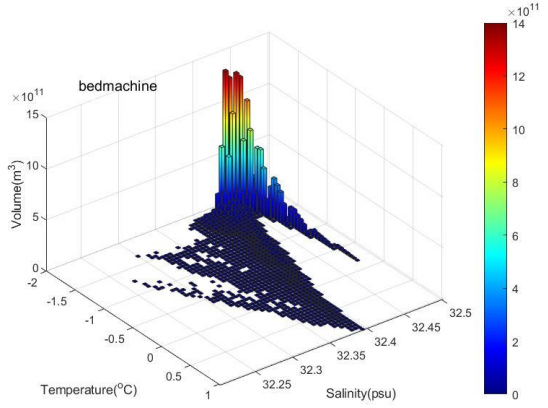
SRTM15

Volume (m^3)



BedMachine

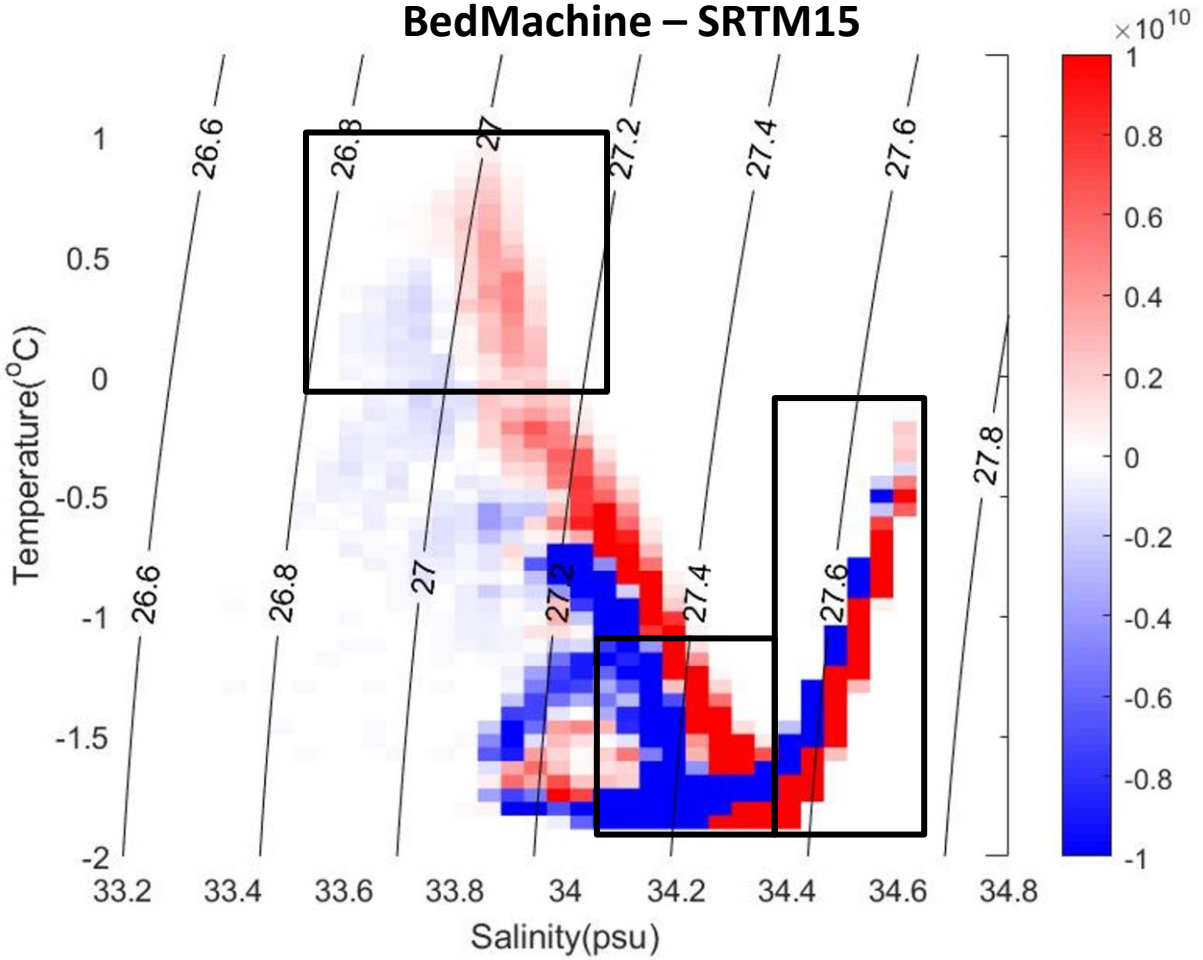
Volume (m^3)



3 – dimensional TS diagrams

Volume (m^3)

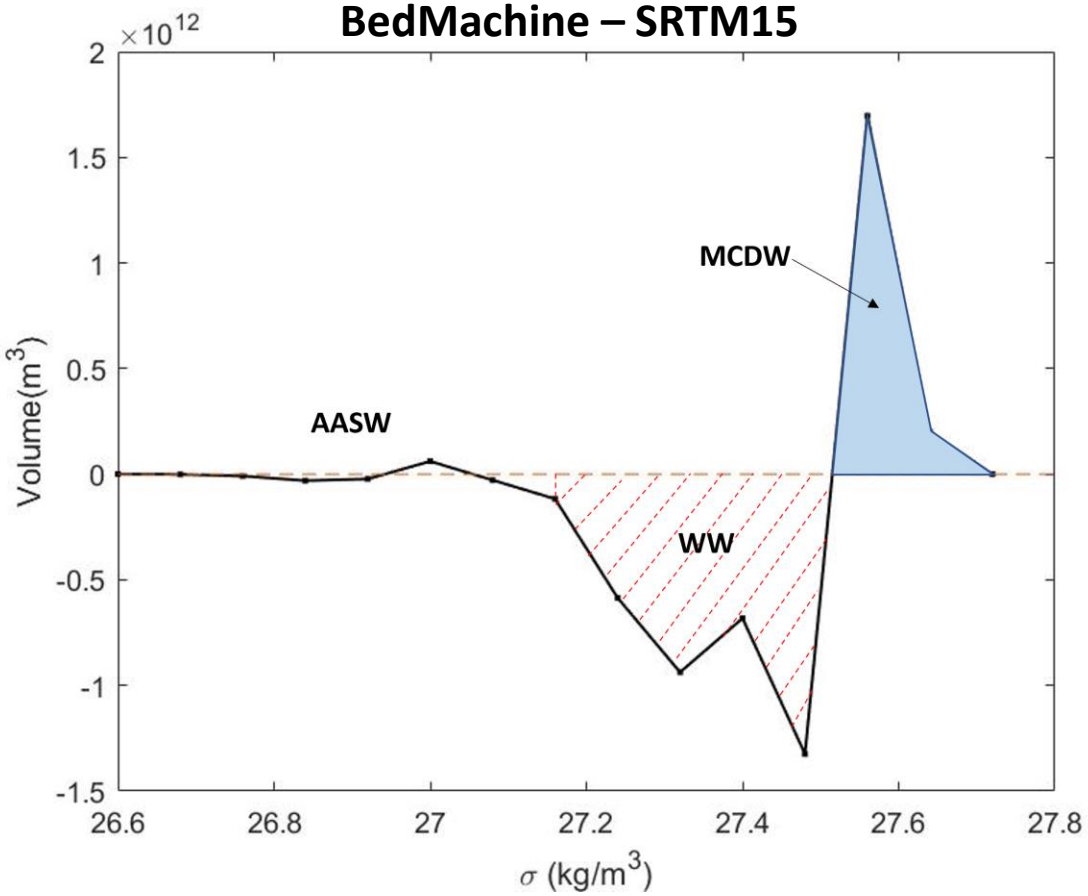
BedMachine – SRTM15



Water properties – TS volume

- Bathymetry profoundly impacts the water mass composition over the shelf.
- Up to 62% more volume of MCDW in BedMachine.

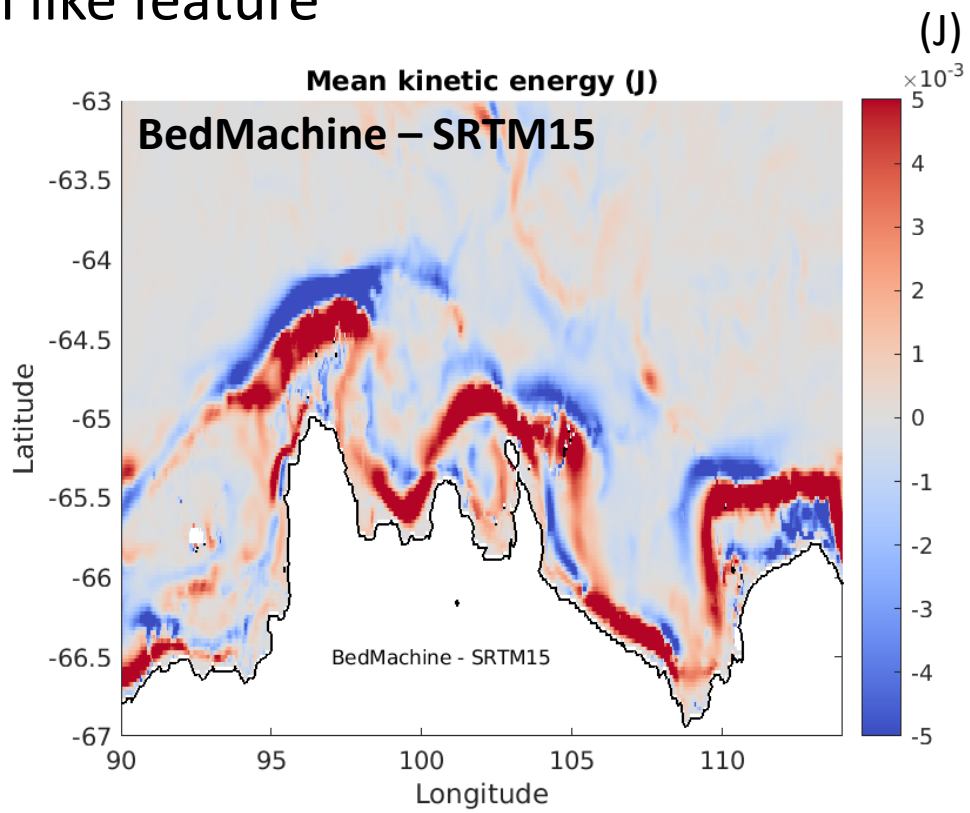
Bathymetry changes the water volumes.

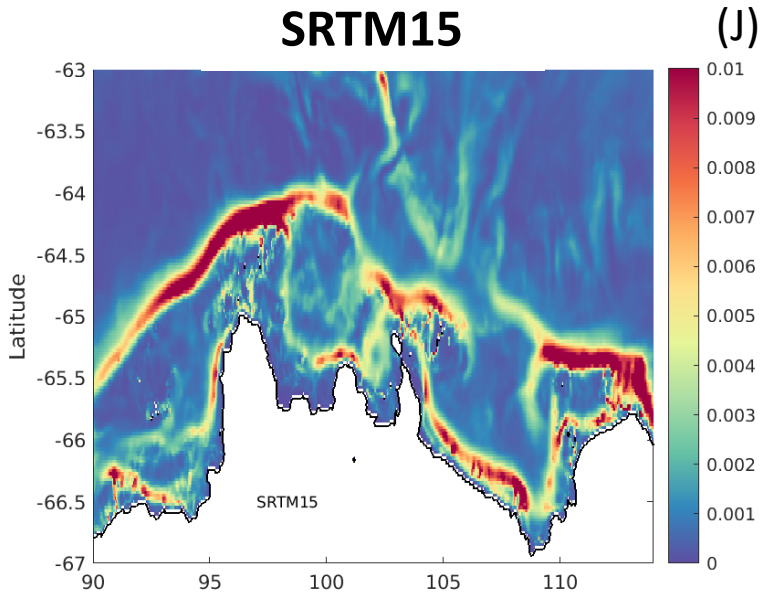


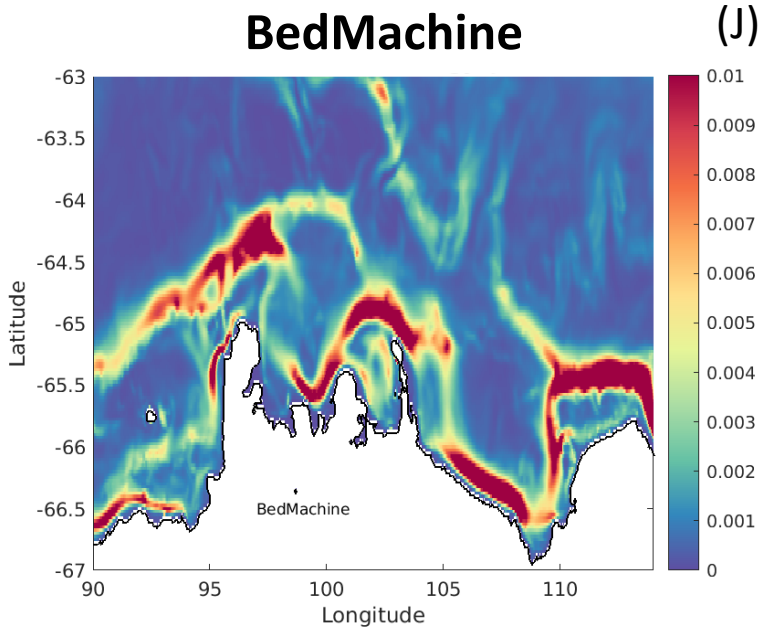
Water mass	MCDW
$\Delta V/V_{srtm15}$ (%)	**62%**

Ocean circulation - MKE

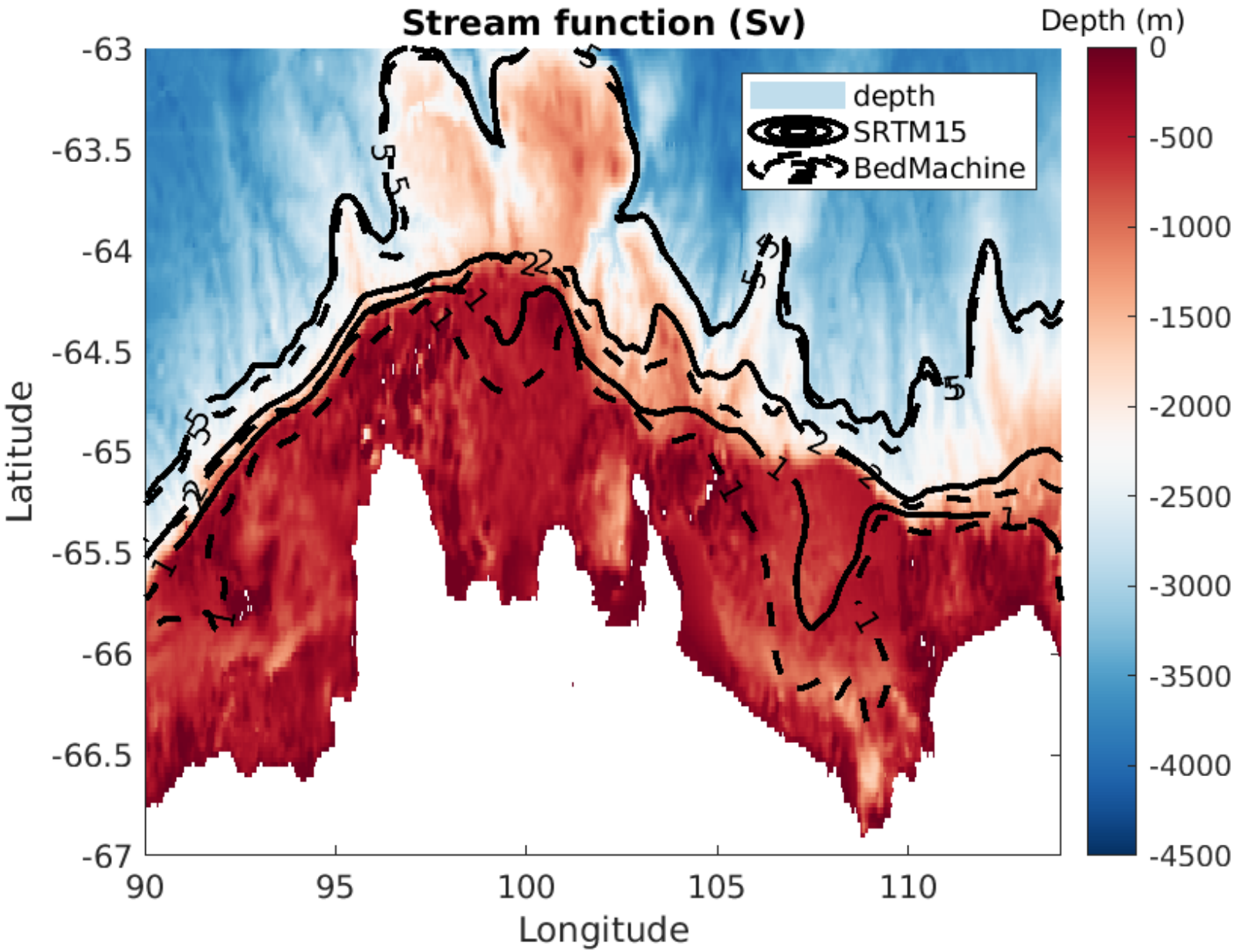
- Position shift of ASC: BedMachine is close to the coast.
  → shift of the shelf break position
- An intensification of the Antarctica Coastal Current (AACC) in the BedMachine.
- The path of the currents is different (eastern side).
  → canyon like feature







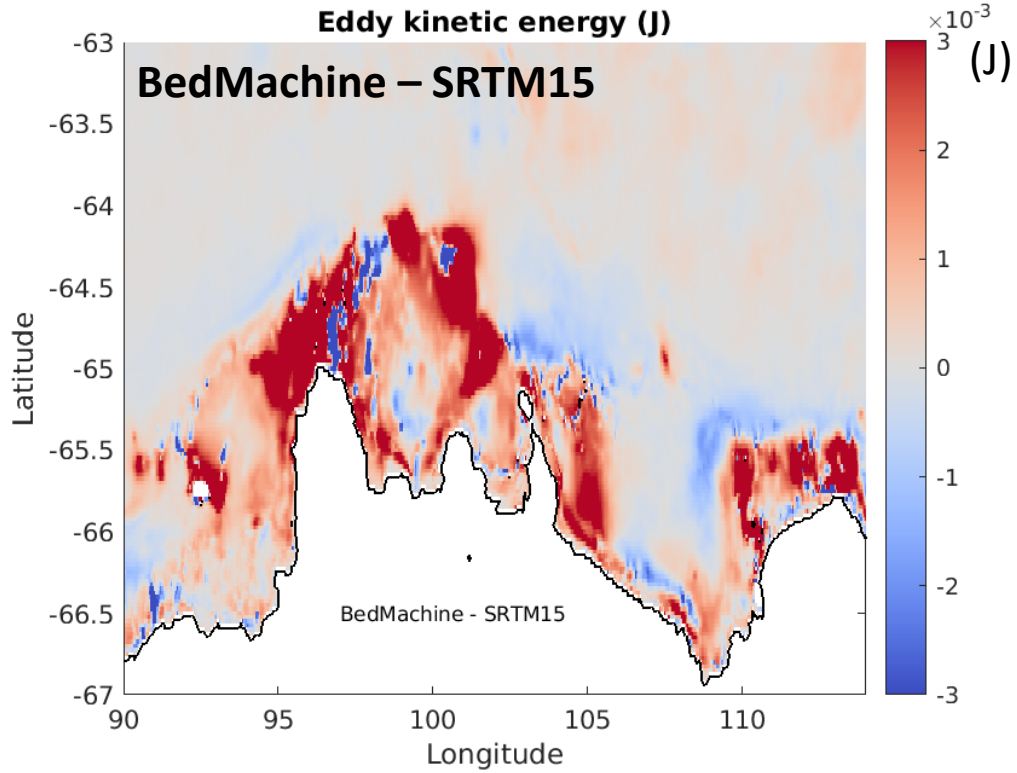
Ocean circulation – stream function

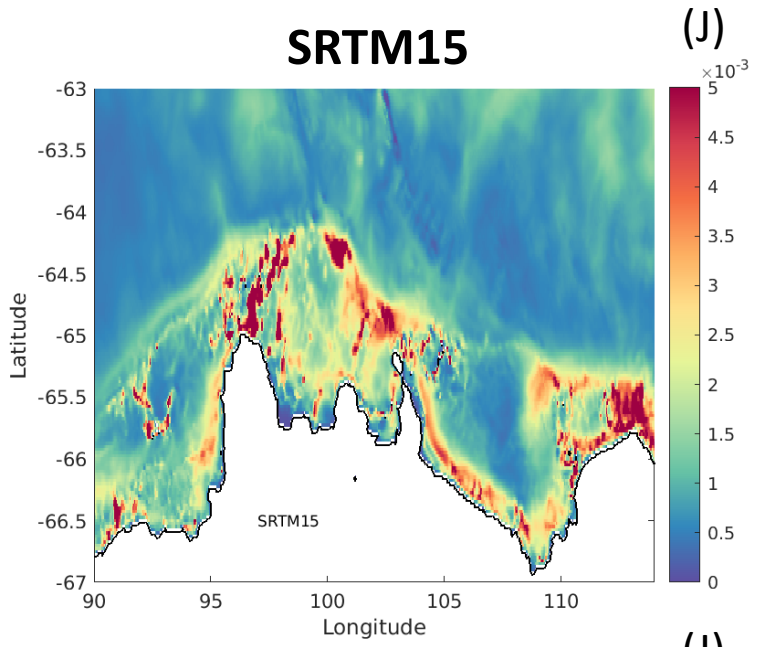


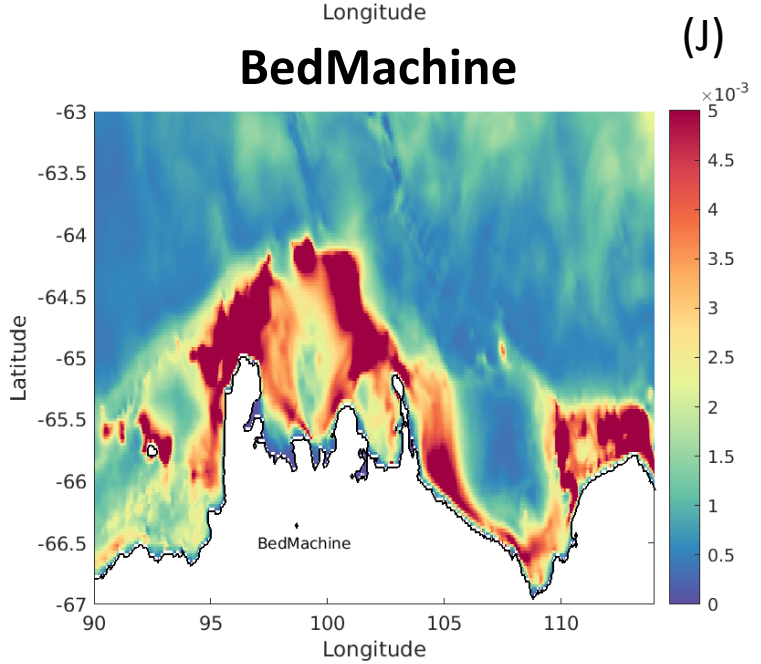
- The current transport is stronger in the shelf break region than near the coastline.
- AACC is stronger and active near the coast in BedMachine

Ocean circulation - EKE

- The magnitude of EKE is much lower than MKE and mainly enhanced near the coastline.
  → higher variability associated with the AACC
- The strength of the variability (eddies) in BedMachine is higher than in SRTM15.
  → likely related to the seafloor roughness







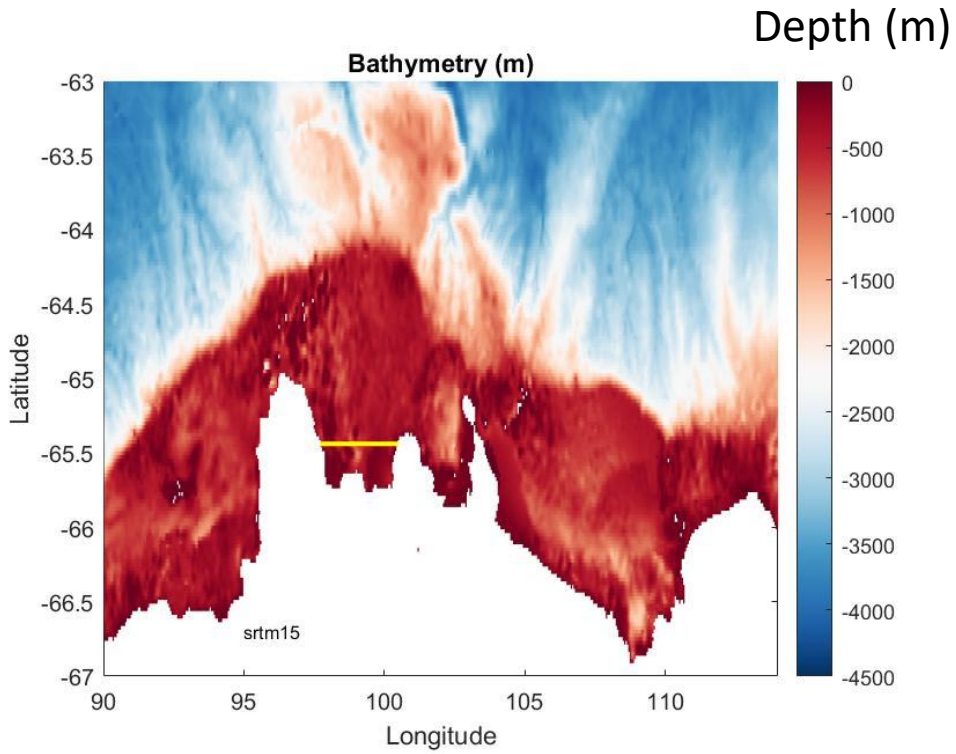
Heat flux

- Mean value:
  SRTM15: -0.9 TW (heat transport to south)

  22% increase

  BedMachine -1.1TW (heat transport to south)

- BedMachine transports more heat to the south.



- Possible reasons: intense AACC with stronger MKE and EKE in the BedMachine

Take home message

- **Bathymetry strongly controls the local circulation and heat transport across the shelf.**

  Differences are shown in
  1) the position and strength of slope and coastal currents
  2) water-mass properties and volumes
  3) heat transport.

- **Emphasize the need for reliable and high-resolution bathymetry.**

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