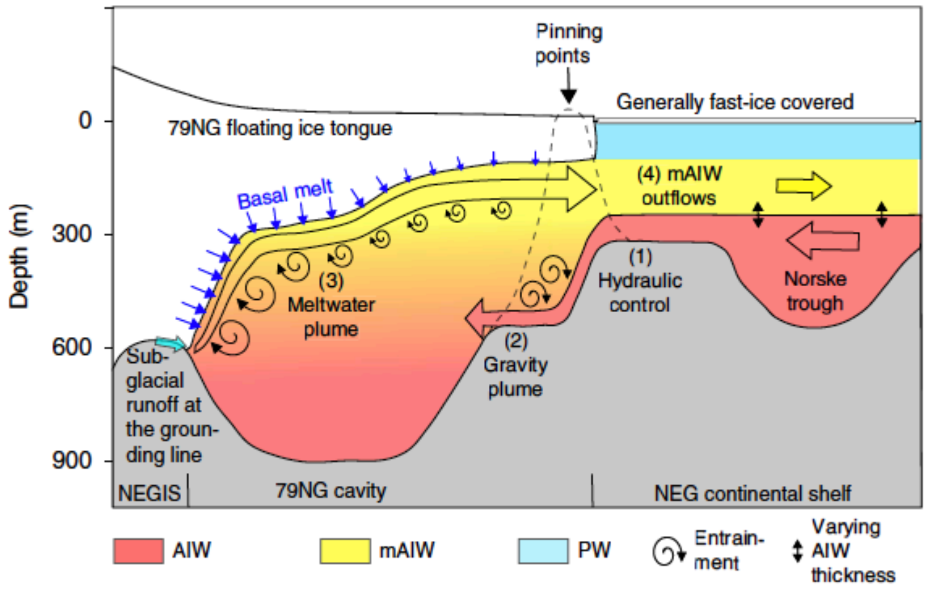
Regional Ice-Ocean studies in the Arctic and Antarctic with FESOM (RIO)

Claudia Wekerle, Mathias Campos van Caspel, Verena Haid, Hartmut Hellmer, Ole Richter, Ralph Timmermann

We use global FESOM configurations to study regional phenomena.

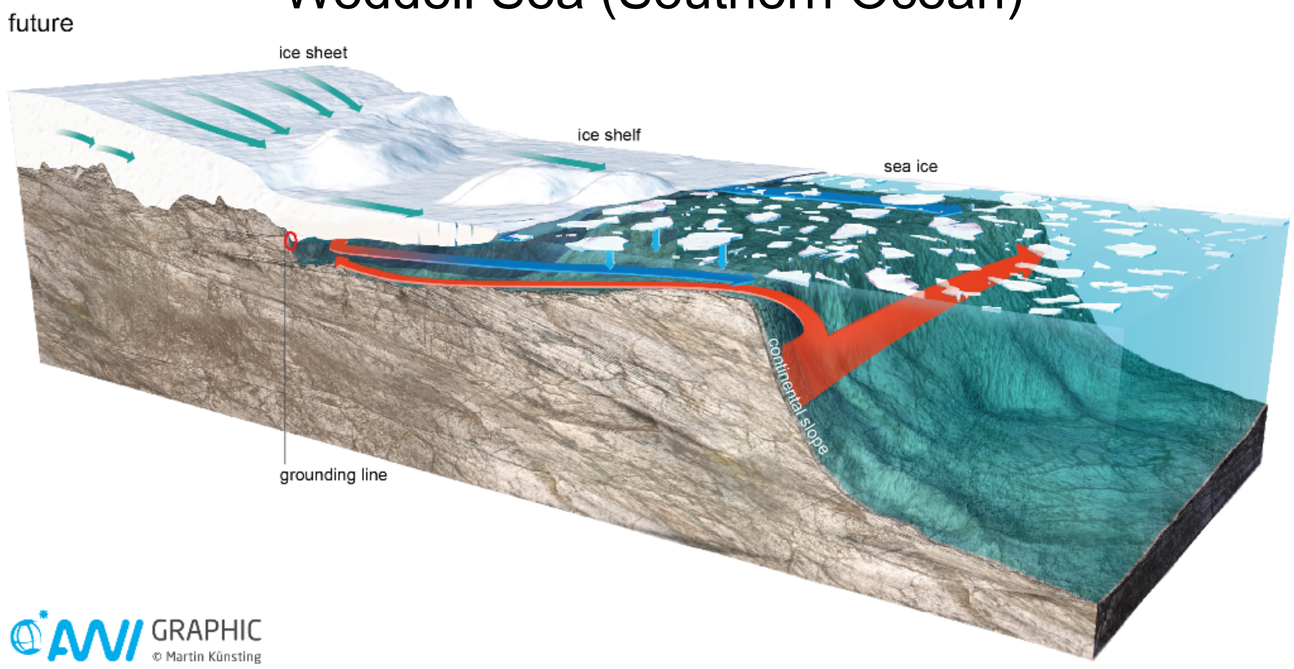
Framework and motivation

79N glacier (Arctic Ocean)



Cavity circulation and water masses at the 79N Glacier
(Schaffer et al. 2020)

Weddell Sea (Southern Ocean)

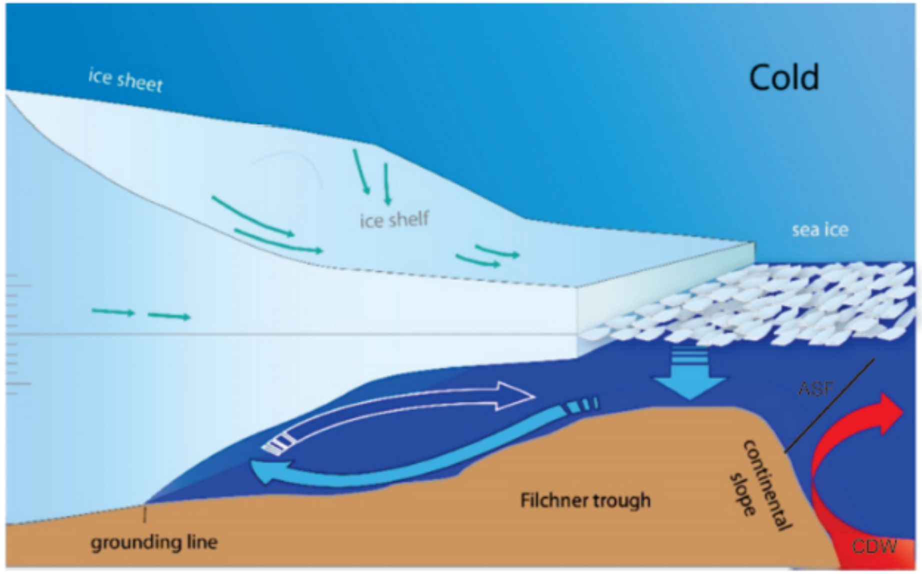


Potential redirection of warm water pathway in the Weddell Sea into Filchner-Ronne Ice Shelf cavity after 2070
(Hellmer et. al., 2012, Timmermann and Hellmer 2013)

We are interested in the ocean‘s response to a warming world, including potential tipping points and the effect on sea level rise

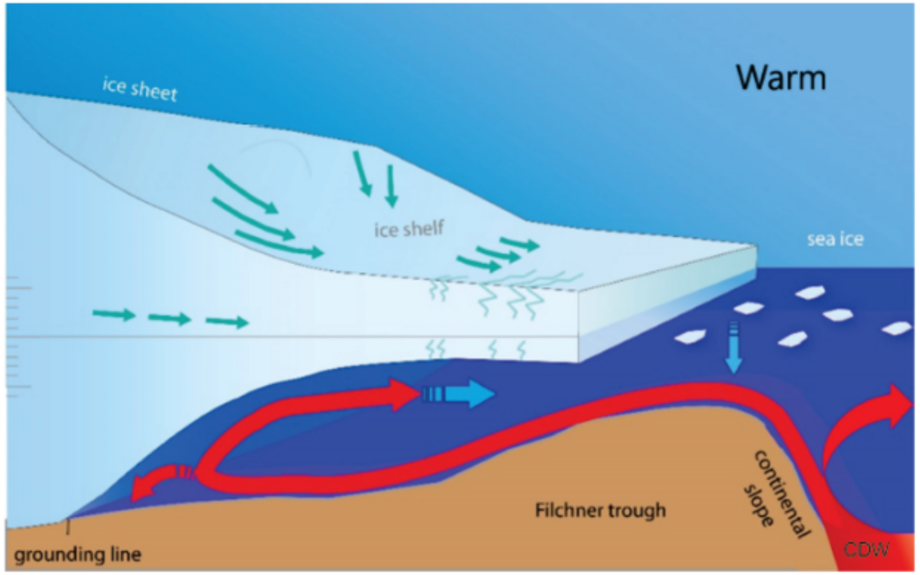
TiPACCs: Tipping Points in Antarctic Climate Components

Verena Haid, Hartmut Hellmer, Ralph Timmermann



Investigation of two tipping points:

1. Ocean cavity state tips from ‚cold‘ to ‚warm‘ state triggering a sudden increase in melt rates
2. Ice sheet grounding line becomes unstable and retreats rapidly



TiPACCs at AWI:

focus on the ocean and the first tipping point of the ocean cavity state

- What triggers it? (in terms of atmospheric forcing)
- What is its impact? (basal melt, sea level…)
- How are the two tipping points related?

Models (current and planned):

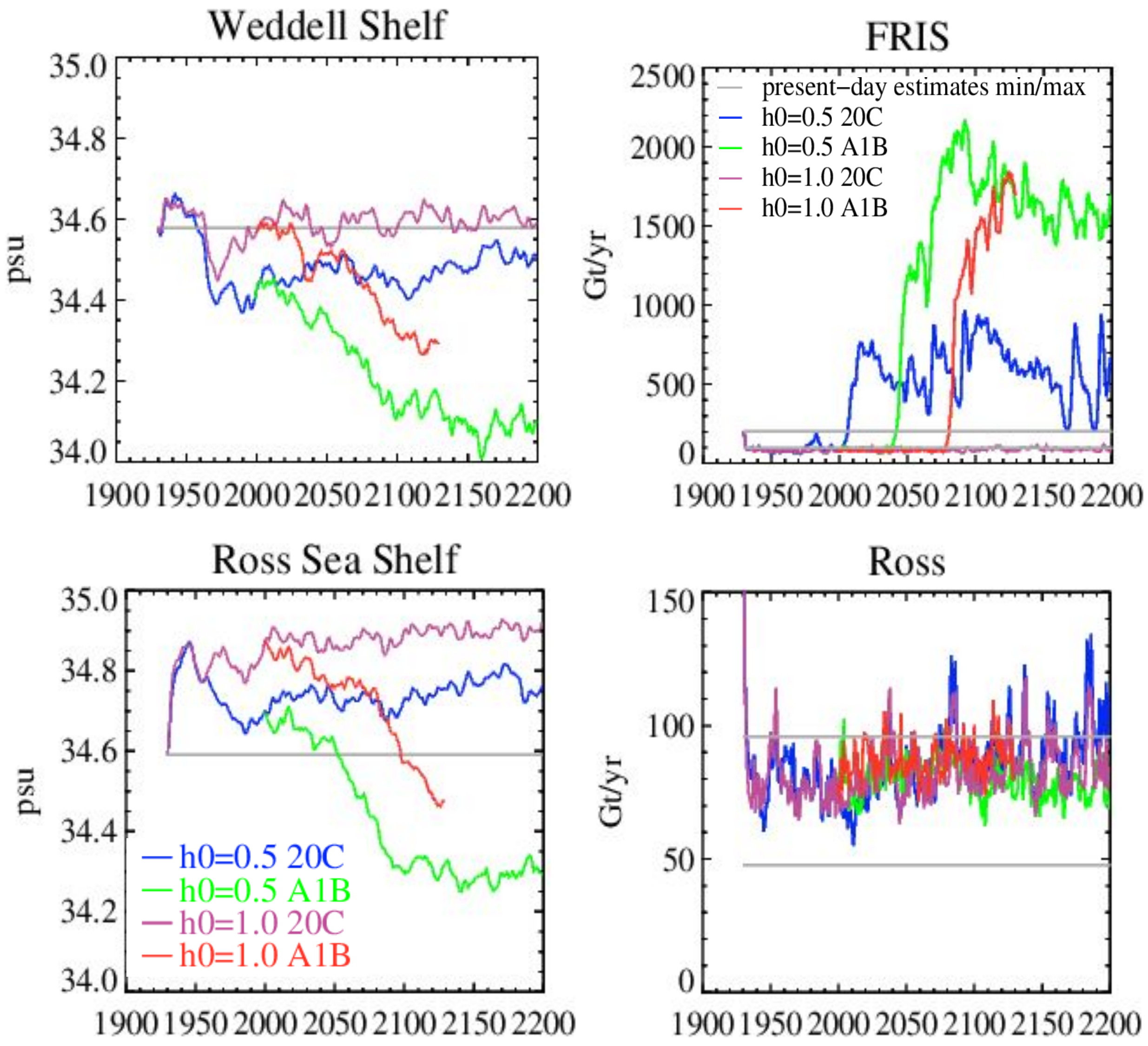
- FESOM1.4
- FESOM2.0 (regional)
- coupled with PISM (PIK)

Partner institutions: Northumbria University NEWCASTLE, PIK, NORCE, UGA Université Grenoble Alpes, AWI ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

TiPACCs: the importance of salinity

Verena Haid, Hartmut Hellmer, Ralph Timmermann

mean salinities | melt rates



HadCM3, two pairs of runs:

- With fresh bias in Weddell Sea (lead closing param. h0=0.5)
- More realistic in WS (h0=1.0)

Each pair:

- repeated 20th century forcing and
- A1B climate scenario from 2000

In Weddell Sea: critical salinity: ~ 34.4 psu

With fresh bias: spontaneous ‚tipping' even in 20C run, A1B tips ~2040

h0=1.0: A1B tips ~2080, 40 years later, with 20C forcing: no tipping

Ross Sea always with salty bias

BUT: distinct freshening in A1B run, however STILL no tipping!

Ross Sea (in FESOM) surprisingly robust

Coupled ocean–sea ice–ice shelf–ice sheet modelling with FESOM-PISM

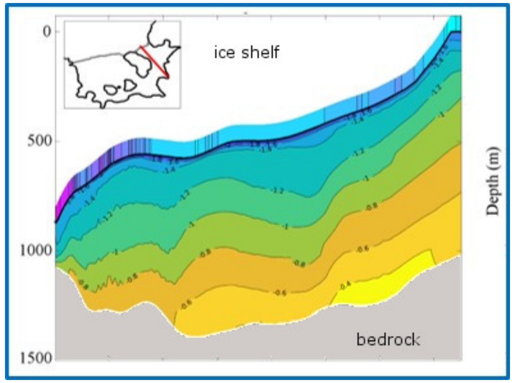
Ralph Timmermann, in coop. with Torsten Albrecht (PIK)

AWI

Goal: Investigate ocean–cryosphere interaction through ice shelves with varying cavity geometry

FESOM-1.4

- domain: global
- horizontal resolution: 1.9 – 250 km
- Hybrid vertical coordinate (terrain-following in cavities)
- 3-equation model of ice shelf-ocean interaction



coupler

ice shelf basal melt rates, boundary layer temperatures

currently: once/yr

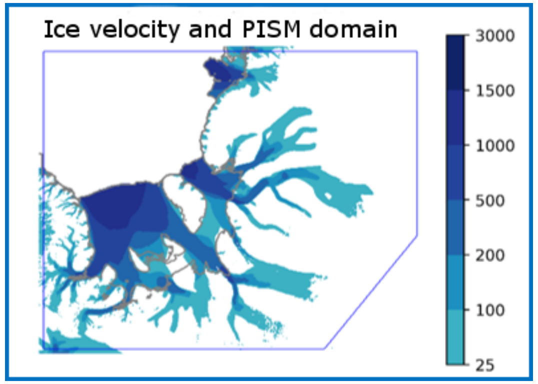
ice shelf thickness, near-base temperature, GL position

updated FESOM mesh (new cavity geometry) and ice temperature

upgraded from Timmermann&Goeller (2017)

PISM

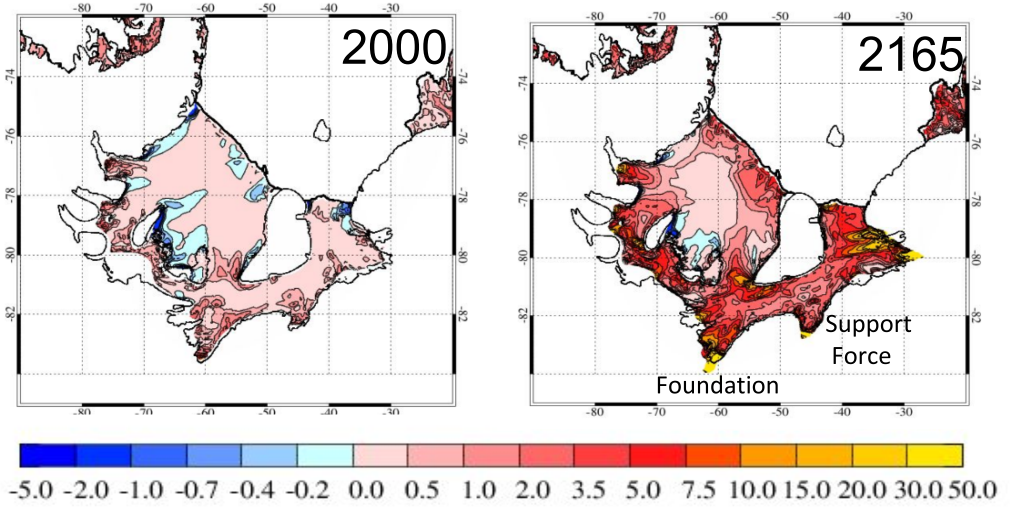
- domain: FRIS + catchment area
- horizontal resolution: 1 km
- vertical resolution: 401 sigma layers
- ice dynamics: SIA-SSA hybrid
- 900 yr spin-up
- to date: prescribed calving front

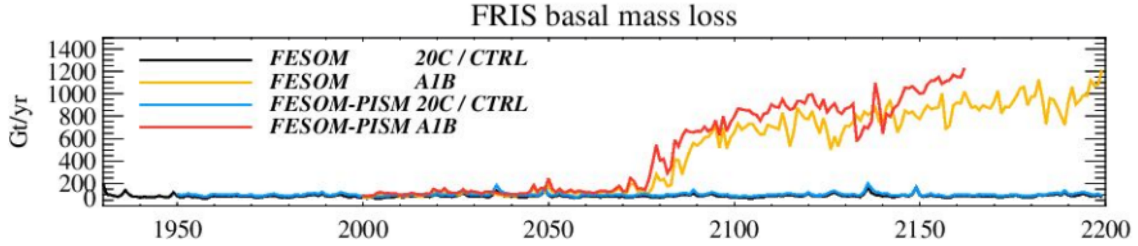


Coupled ocean–sea ice–ice shelf–ice sheet modelling with FESOM-PISM

Ralph Timmermann, in coop. with Torsten Albrecht (PIK)

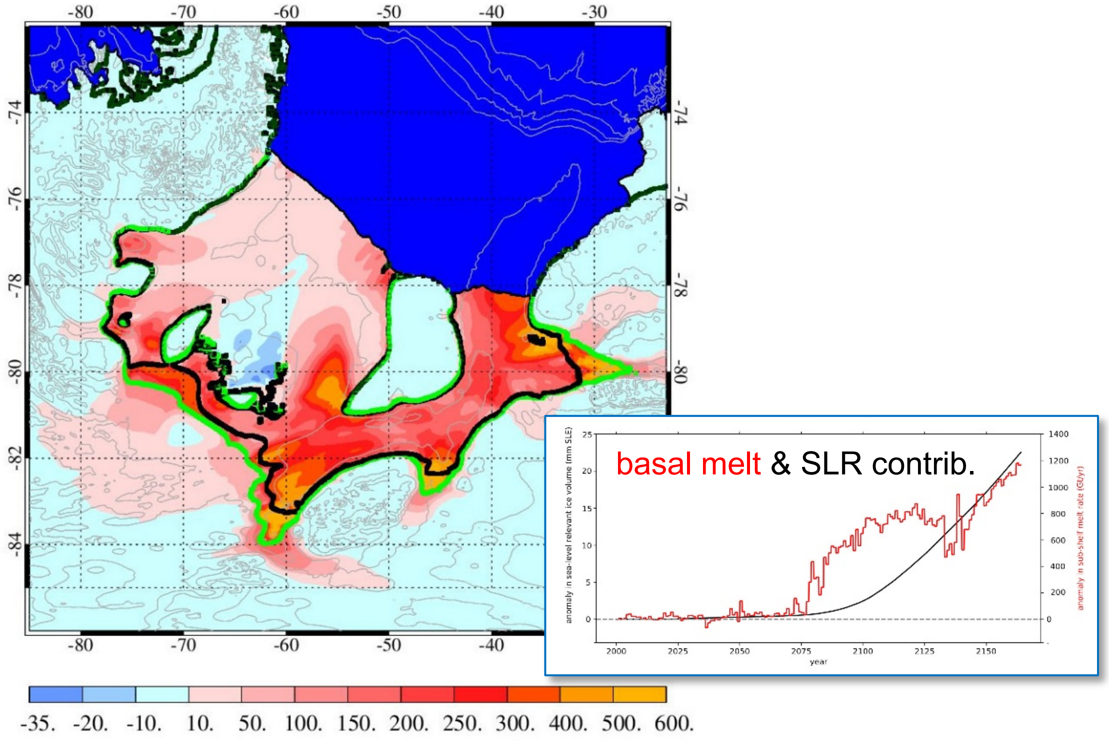
Results from climate change projections until 2200:





- Strong increase of basal melt rates after 2075
- Coupled response stronger than with fixed cavity geometry

Ice sheet/shelf thinning & grounding line migration:



- thickness reduction by up to 70%
- 2.5 cm SLR contribution by 2165 from FRIS catchment basin

Ice Sheet Coupling: PROTECT

Ole Richter and Ralph Timmermann

PROjec**T**ing s**E**a-level rise : from i**C**e sheets to local implica**T**ions

- EU-funded project: 10 Million for 4 years
- Improve global and regional SLR projection
- Improve our understanding of ice sheet-atmosphere-ocean interactions
- Envision the future social impact of SLR

FESOM's role:

- Coupling FESOM with ice sheet model Ua
- Unstructured meshes in both components!
- Participate in Model Intercomparison Projects (idealized and realistic)
- Antarctic contribution to sea level rise until 2100

Ice Sheet Coupling: PROTECT

Ole Richter and Ralph Timmermann

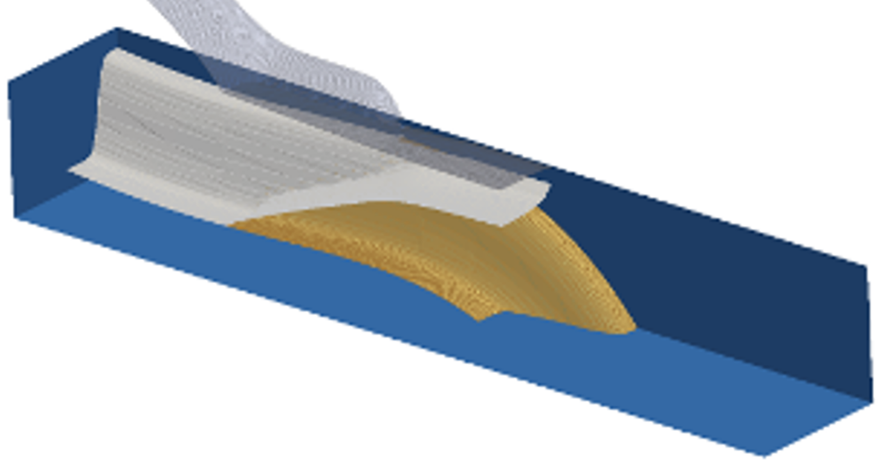
Testing Ua in idealized conditions

- **M**arine **I**ce **S**heet **M**odel **I**ntercomparison **P**roject
- Benchmark for Ice-Flow models
- Reproduced some results with Ua
- Testing, training, preparation for coupling

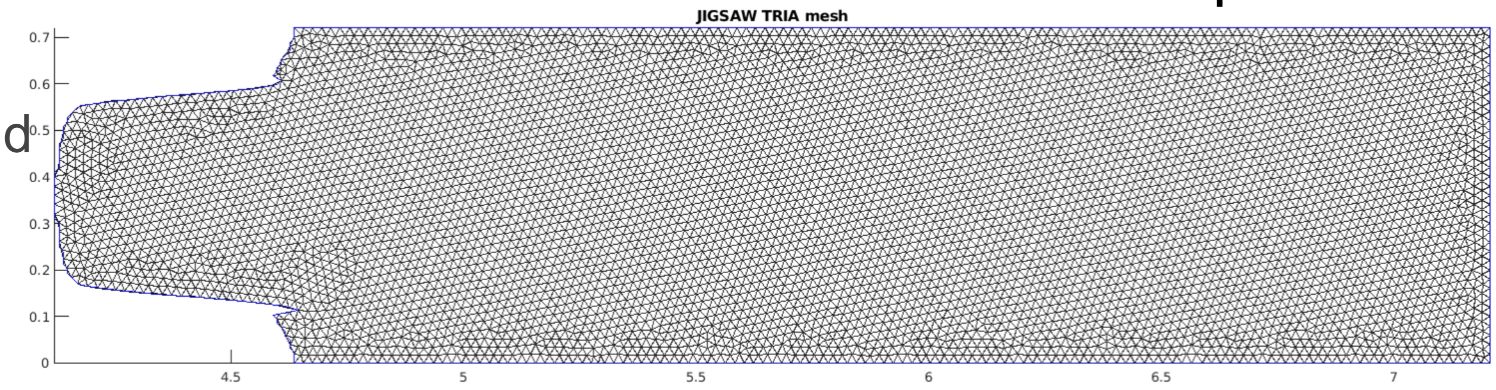
Preparing FESOM for idealized experiments

- **I**ce **S**helf-**O**cean **M**odel **I**ntercomparison **P**roject
- Mesh generation done
- Now: set-up of idealized forcing and boundary conditions

Domain of idealized coupled experiment



Fesom mesh for the ocean component



Ice shelf-sea ice-ocean simulations with FESOM2

Mathias van Caspel and Ralph Timmermann

1. **Global setup**
   - Compare with FESOM1.4 and get familiar with FESOM2
   - Use available Z-level mesh

Status:
- Ice shelf cavities: look ok
- Sea ice: testing configuration

Next steps:
- Improve agreement between model & observation

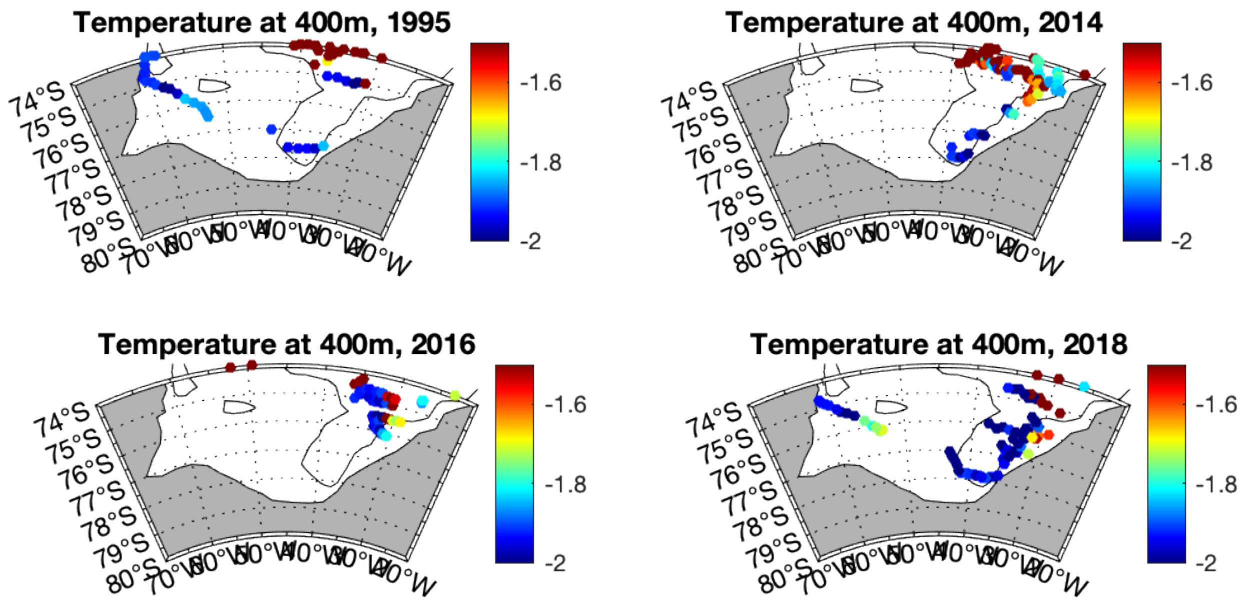
2. **Regional setup for Wedell Sea**
   - Increase resolution
   - Controlled boundary conditions

Next steps:
- Create mesh & setup for FESOM2 regional runs
- Select boundary conditions

Marine Ice Sheet Ocean Model Intercomparison Project (MISOMIP2)

Mathias van Caspel and Ralph Timmermann

- **Realistic forcing and model geometries**
- **Regional Foci:**
    - Amundsen Sea
    - Weddell Sea
- **Simulations:**
    - Standalone ocean
    - Standalone ice sheet
    - Coupled ice sheet-ocean
- **Simulation time frame:**
    - 1990-2020
- **Topography and forcing:**
    - “come as you are“



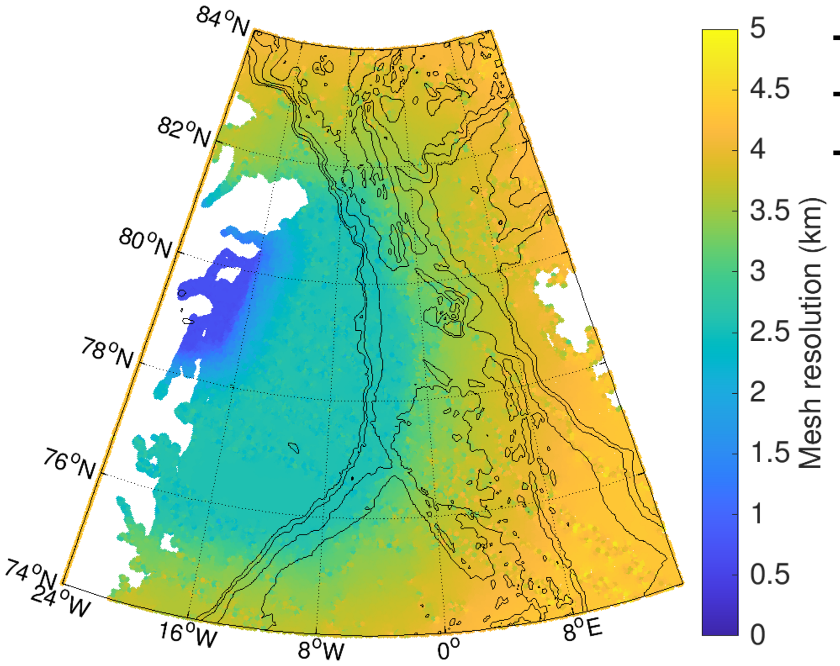
Status:
- Preparing observations
- Discussing metrics to evaluate model „quality“

Brains behind the idea: Jan **De Rydt**, Nicolas **Jourdain**, Yoshihiro **Nakayama**, Ralph **Timmermann**

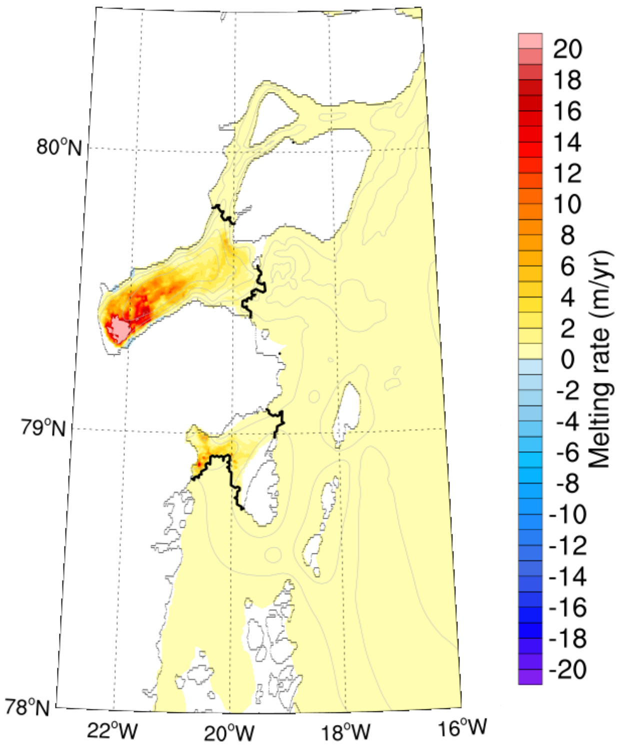
Greenland Ice sheet Ocean Interaction (GROCE2)

Claudia Wekerle, Qiang Wang and Ralph Timmermann

1. From the continental shelf to the grounding line: Which processes are responsible for the heat transport towards the 79NG
2. What are the reasons for high melt rates at the base of 79NG?
3. Climate projections: how stable is the 79NG?



→ AO + Nordic Seas: 4.5 km
→ NE Greenland shelf: 2.5 km
→ 79NG: 700 m



Status:

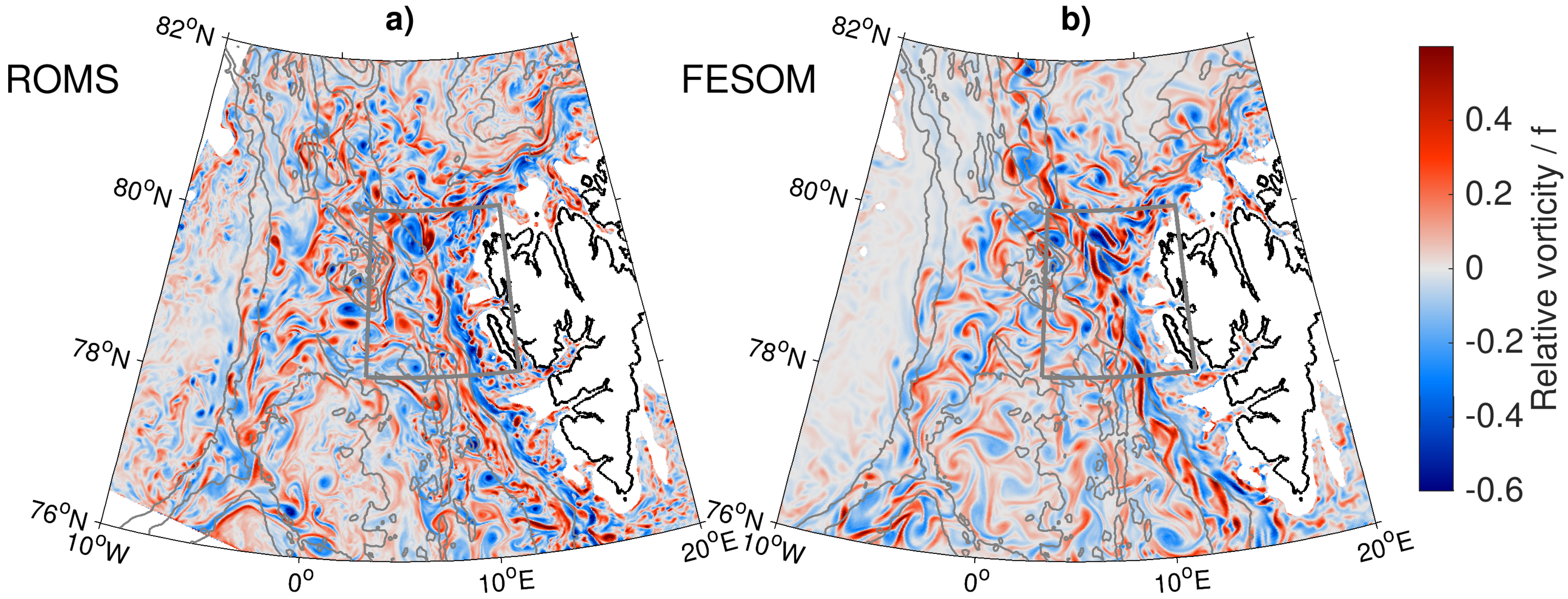
- Testing mesh configurations with FESOM1.4

Next steps:

- FESOM2 cavity code from Patrick
- Coupling with ice sheet model ISSM (together with Martin Rückamp)

Eddy dynamics in Fram Strait (FRAM)

Claudia Wekerle, Tore Hattermann, Qiang Wang, Sergey Danilov et al

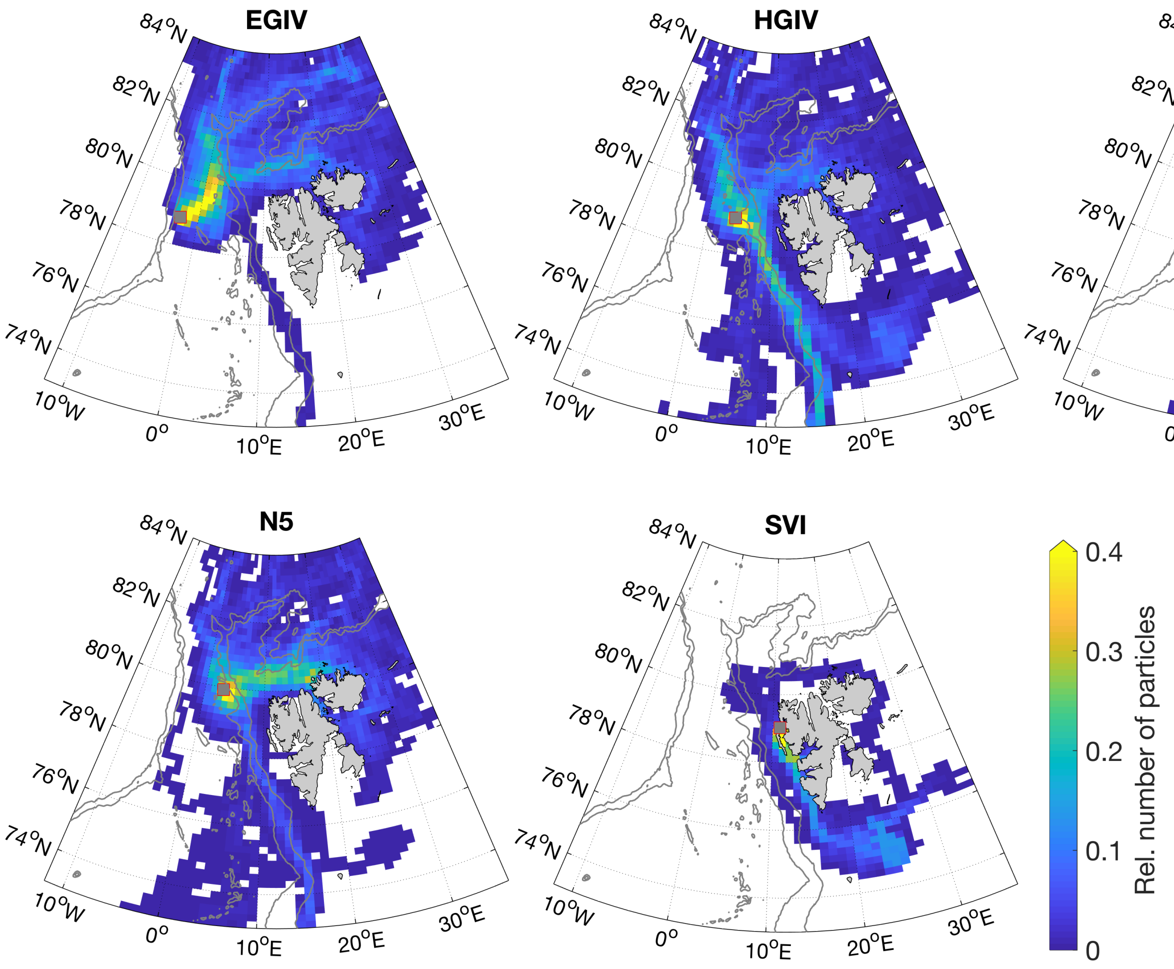


Wekerle et al. (2020): Properties and dynamics of mesoscale eddies in Fram Strait from a comparison between two high-resolution ocean–sea ice models

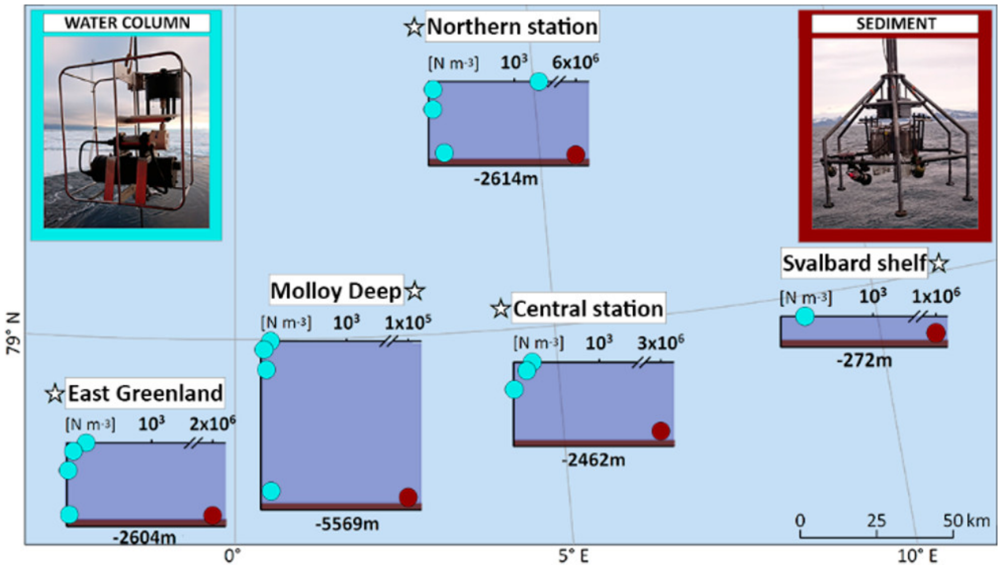
→ good agreement between ROMS and FESOM in terms of eddy properties
→ both models simulated similar pattern of energy transfer

Lagrangian modelling with FESOM (FRAM)

Mine Tekman and Claudia Wekerle



Source areas of MP particles detected at the near-surface depth layers at five stations of the HAUSGARTEN Observatory



Tekman et al. (2020): Microplastic Pollution in the Arctic

Conclusions

→ Focus on ice sheet-ice shelf-ocean interactions

→ From process understanding to future projections

→ Taking part in MIPs (MISOMIP2 / ISOMIP)