EGU21-10448

Representation of Basal Melting in Idealised Coupled Ice Sheet Ocean Models

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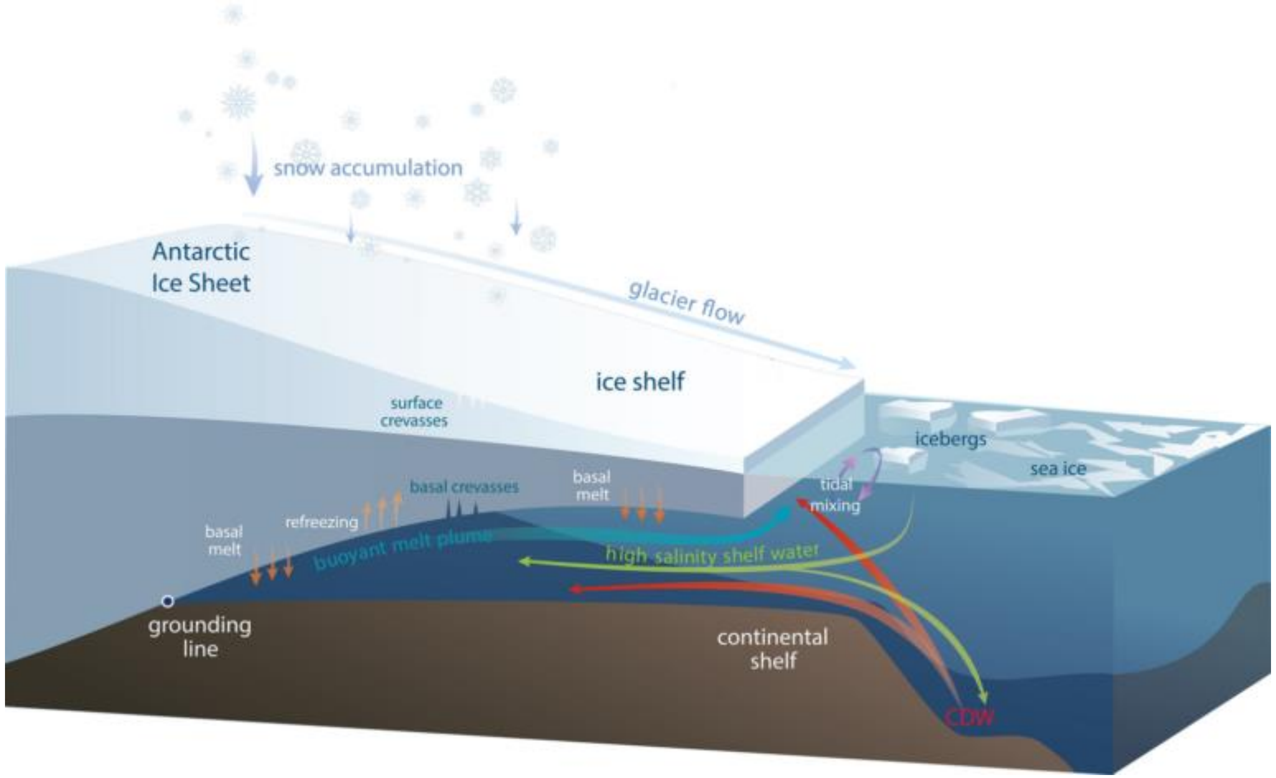
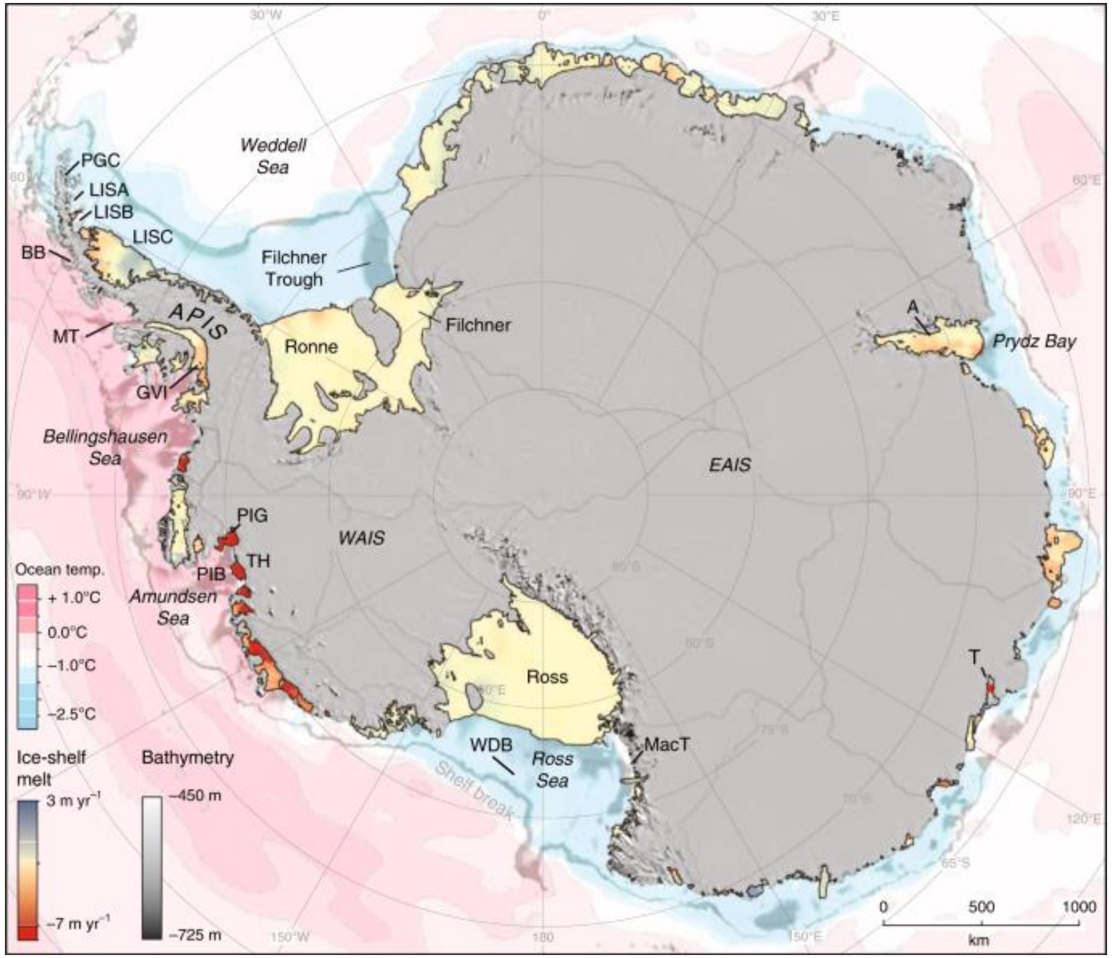
Ice-Ocean Interaction



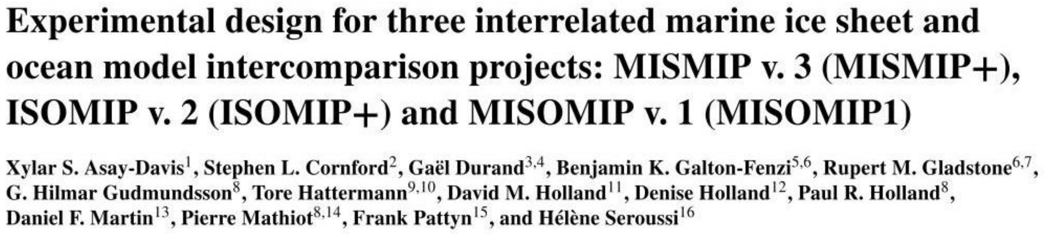
(Helen A. Fricker, Scripps Institution of Oceanography)



Ice shelf thinning rates during 2003-2008
(Pritchard et al., 2012)

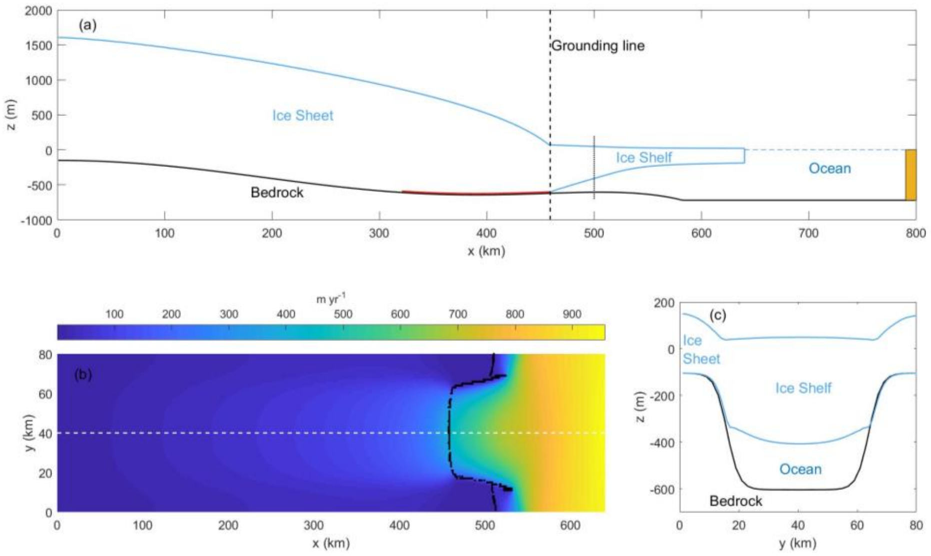
Model Description

- MISOMIP1



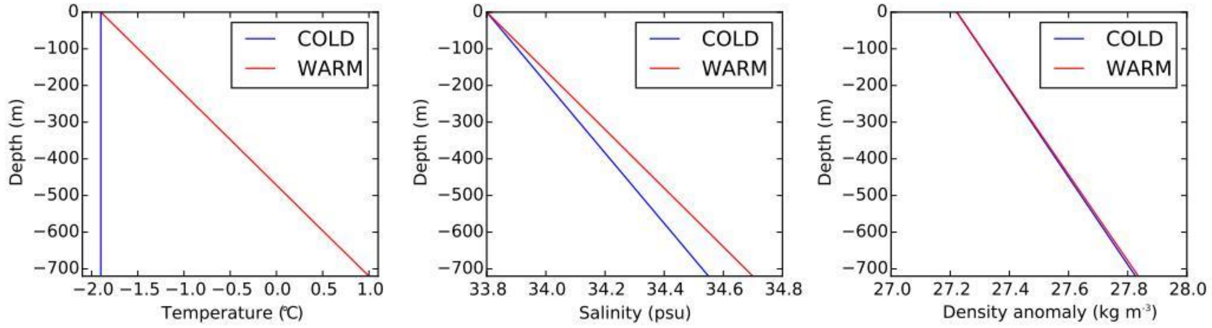
Experimental design for three interrelated marine ice sheet and ocean model intercomparison projects: MISMIP v. 3 (MISMIP+), ISOMIP v. 2 (ISOMIP+) and MISOMIP v. 1 (MISOMIP1)

Xylar S. Asay-Davis[1], Stephen L. Cornford[2], Gaël Durand[3,4], Benjamin K. Galton-Fenzi[5,6], Rupert M. Gladstone[6,7], G. Hilmar Gudmundsson[8], Tore Hattermann[9,10], David M. Holland[11], Denise Holland[12], Paul R. Holland[8], Daniel F. Martin[13], Pierre Mathiot[8,14], Frank Pattyn[15], and Hélène Seroussi[16]



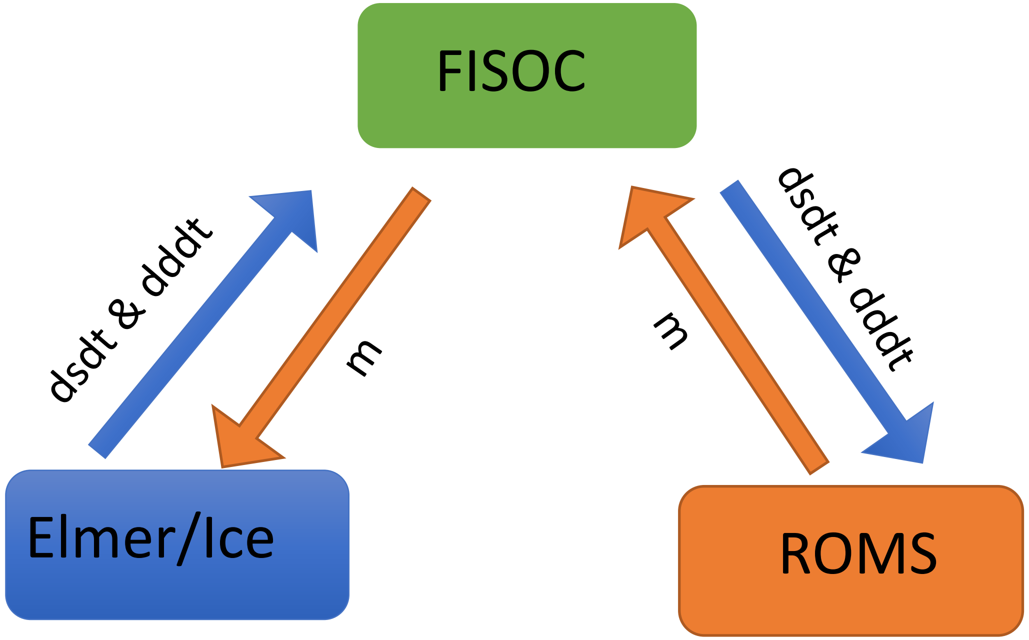
Qualitative similarity to the Pine Island Glacier Ice Shelf and the adjacent Amundsen Sea region → explore the effects of changes in ocean conditions on ice dynamics and basal melting

MISOMIP1 IceOcean1r
100-year coupled run with no dynamic calving, COLD initial conditions and WARM forcing



WARM and COLD temperature, salinity, and density profiles used in MISOMIP1 (Asay-Davis et al., 2016)

Model Description



FISOC

Elmer/Ice

ROMS

dsdt & dddt

m

m

dsdt & dddt

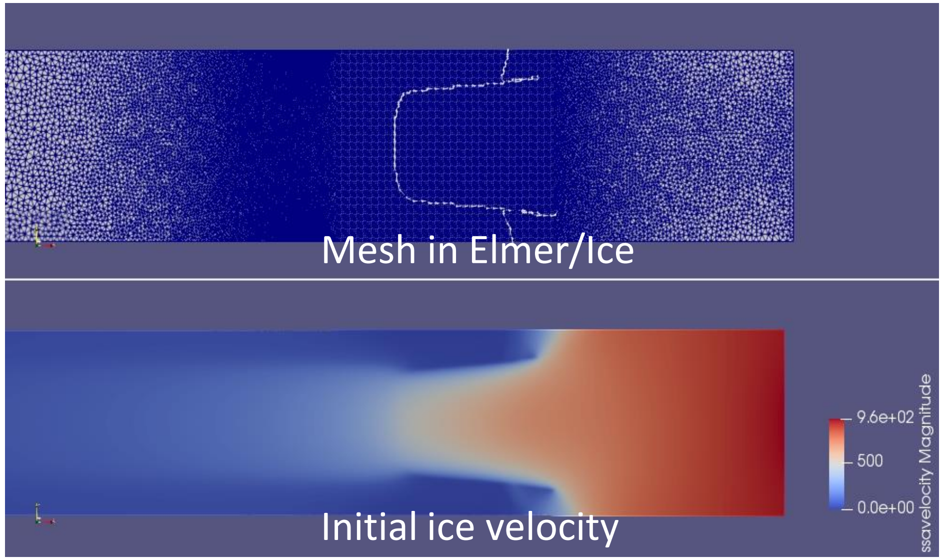
Geosci. Model Dev., 14, 889–905, 2021
https://doi.org/10.5194/gmd-14-889-2021

Model description paper

11 Feb 2021

The Framework For Ice Sheet–Ocean Coupling (FISOC) V1.1

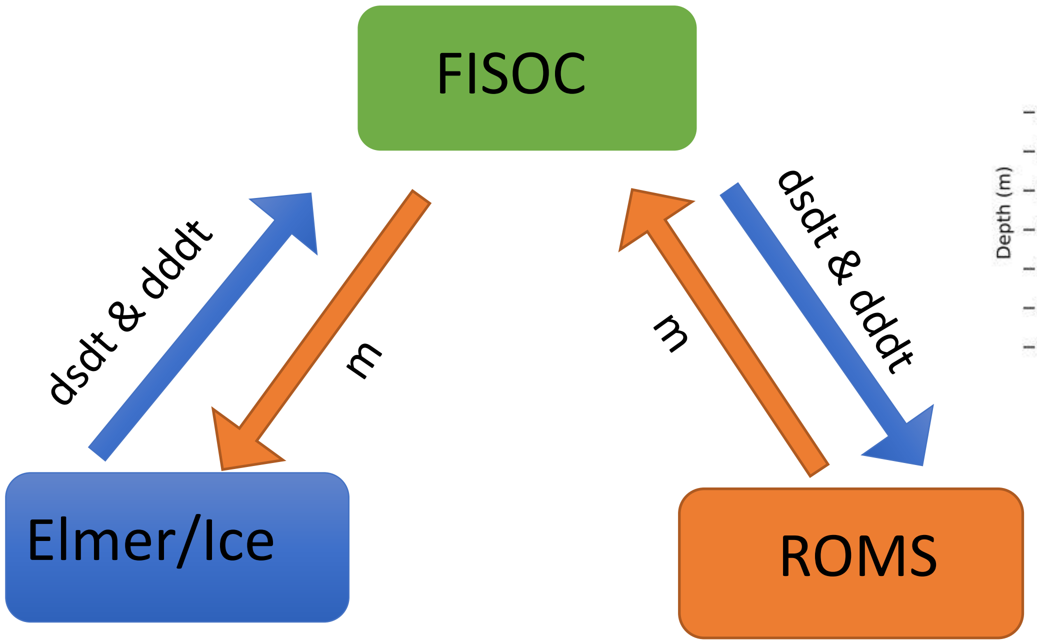
Rupert Gladstone[1], Benjamin Galton-Fenzi[2,3], David Gwyther[3], Qin Zhou[4], Tore Hattermann[5,10], Chen Zhao[3], Lenneke Jong[2], Yuwei Xia[6], Xiaoran Guo[6], Konstantinos Petrakopoulos[8], Thomas Zwinger[9], Daniel Shapero[7], and John Moore[1,6]



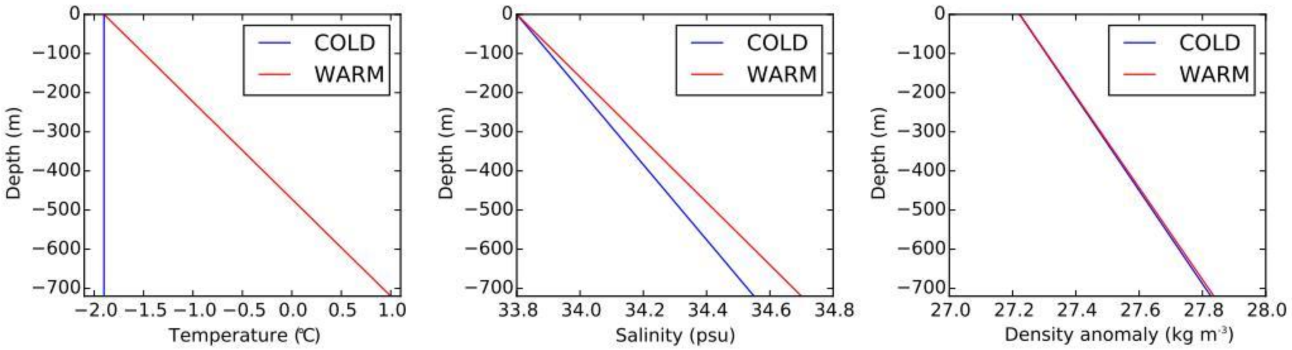
Setup of Elmer/Ice

- Initial condition → steady state ice sheet
- Constant ice temperature
- Thermal conductivity of ice = 0 → only flux across the ice ocean interface is of meltwater
- SSA*

Model Description



dddt: ice draft change rate
dsdt: ice surface elevation change rate
m: basal melt rate

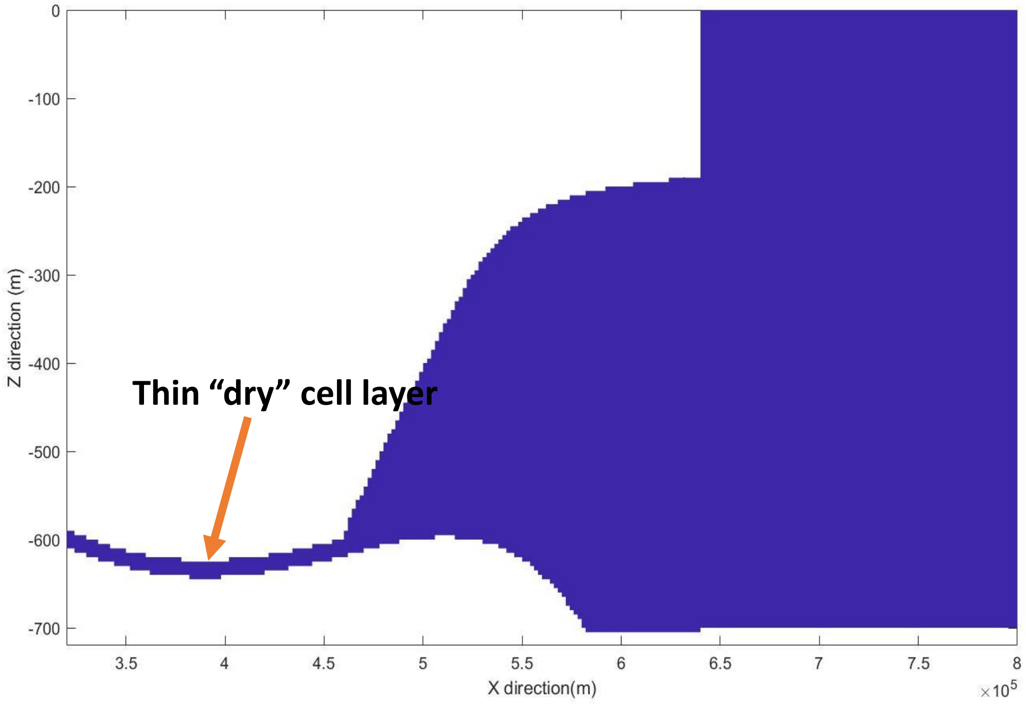


Setup of ROMS

- Initial state
  - steady state ice topography from ice sheet model
  - COLD salinity and temperature profiles
- Only freshwater fluxes → melting water
- WARM forcing → strong melting and rapid grounding line retreat

Model Description

➢ Grounding line movement



"wet-dry” Scheme or “thin film” approach (Medeiros and Hagen, 2013)

- “Dry” cells represent the passive water column under grounded ice
- “wet” cells represent the active water column beneath floating ice or the open ocean.
- An activation criterion for an "dry" cells turning into "wet" is imposed to represent GL retreat.
- If the dynamic variations in ocean pressure are sufficient to overcome the ice pressure due to the positive height above buoyancy, the dry cell can become wet and ungrounded.

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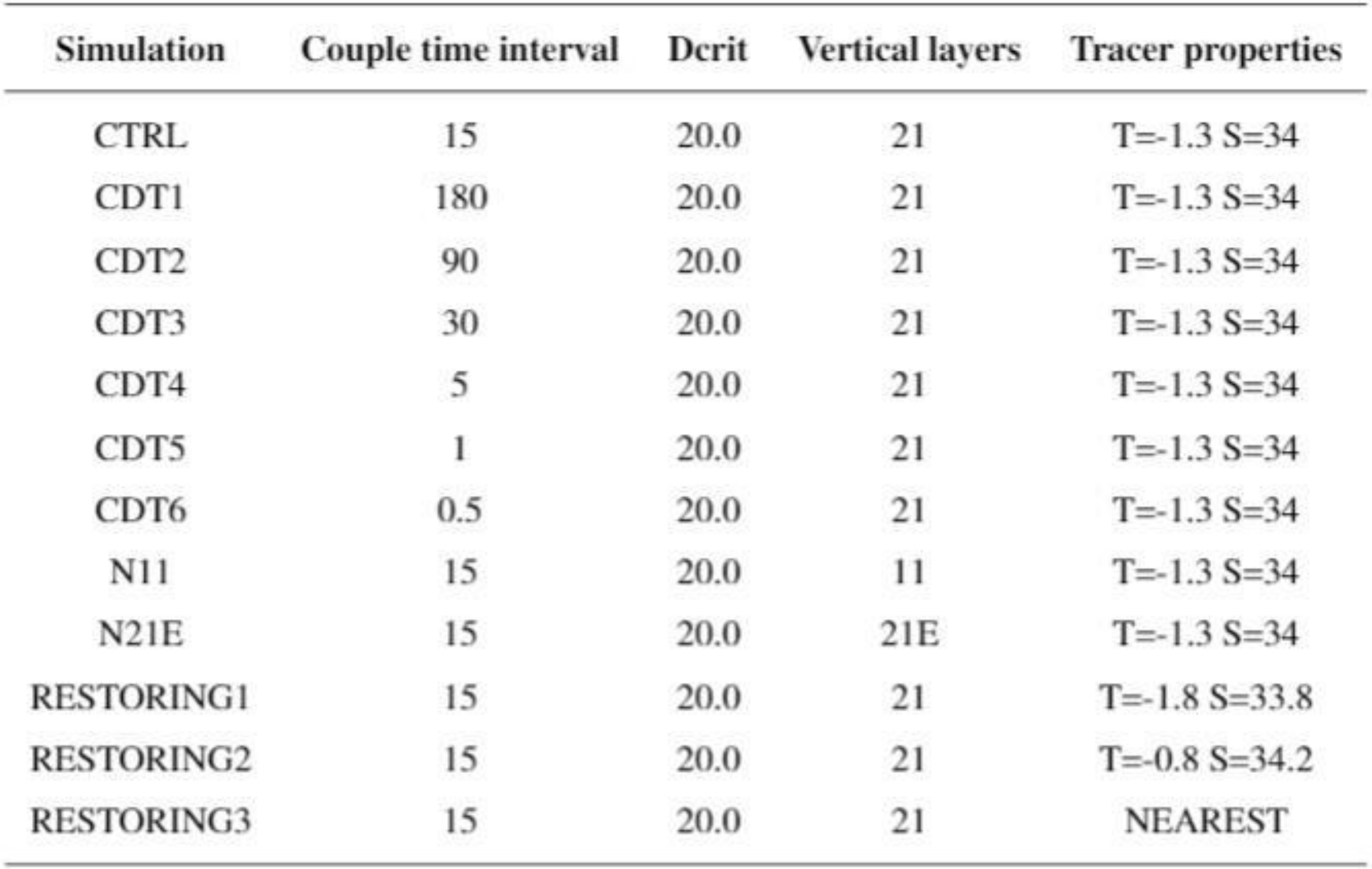
Experiment Design



Simulation	Couple time interval	Dcrit	Vertical layers	Tracer properties
CTRL	15	20.0	21	T=-1.3 S=34
CDT1	180	20.0	21	T=-1.3 S=34
CDT2	90	20.0	21	T=-1.3 S=34
CDT3	30	20.0	21	T=-1.3 S=34
CDT4	5	20.0	21	T=-1.3 S=34
CDT5	1	20.0	21	T=-1.3 S=34
CDT6	0.5	20.0	21	T=-1.3 S=34
N11	15	20.0	11	T=-1.3 S=34
N21E	15	20.0	21E	T=-1.3 S=34
RESTORING1	15	20.0	21	T=-1.8 S=33.8
RESTORING2	15	20.0	21	T=-0.8 S=34.2
RESTORING3	15	20.0	21	NEAREST

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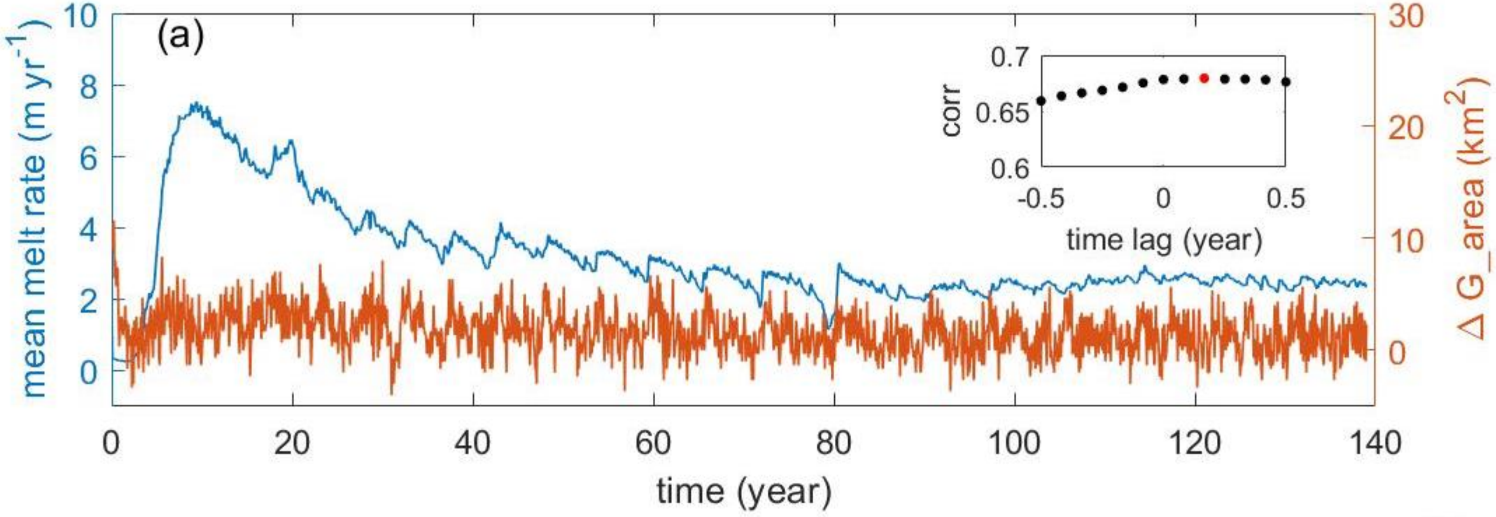
Oscillation pattern of the basal melting rate

Moving changes in grounded area → GL retreat

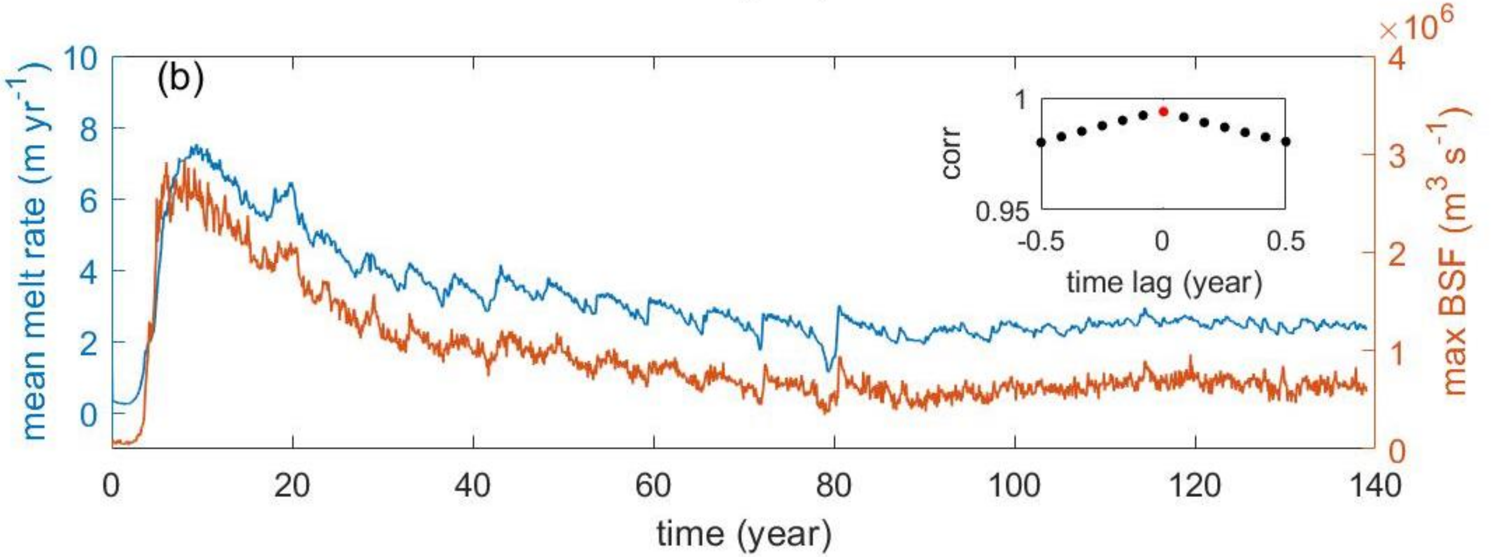


Correlation: 0.71

Time lag: 1 month

- Row-by-row GL retreat comes slightly earlier than the melt peak.
- The melt change due to row-by-row ungrounding is relatively small

Maxima of barotropic stream function → streng of circulation & location of gyre



Correlation: 0.99

Time lag: 0

- basal melting is highly correlated with the gyre circulation near GL

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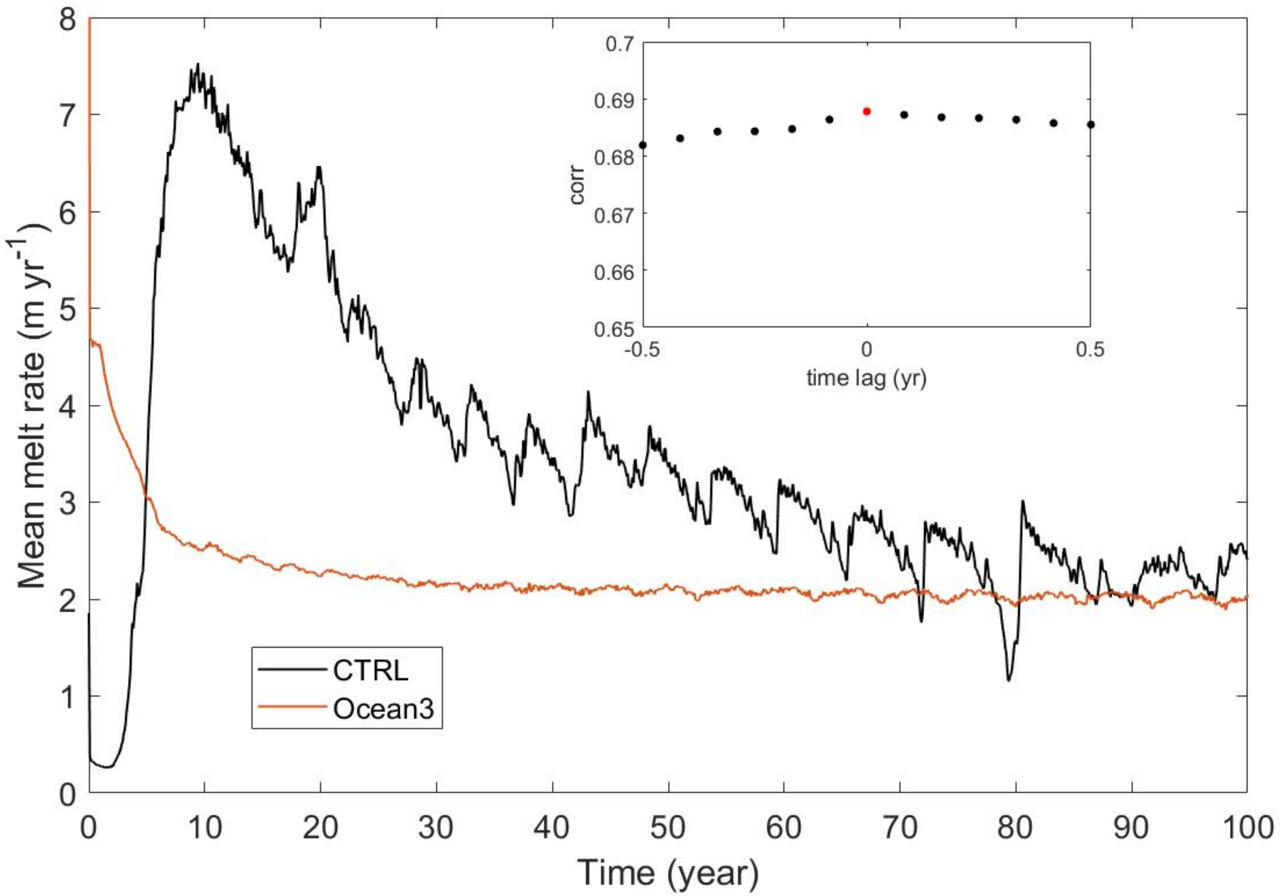
Oscillation pattern of the basal melting rate



- ISOMIP+ Ocean3
  - ROMS-only test
  - 100-year run with dynamic topography changing every year, WARM initial conditions and WARM forcing.

Similar oscillation in Ocean3 proves that row-by-row ungrounding drives the melt oscillation rather the way around.

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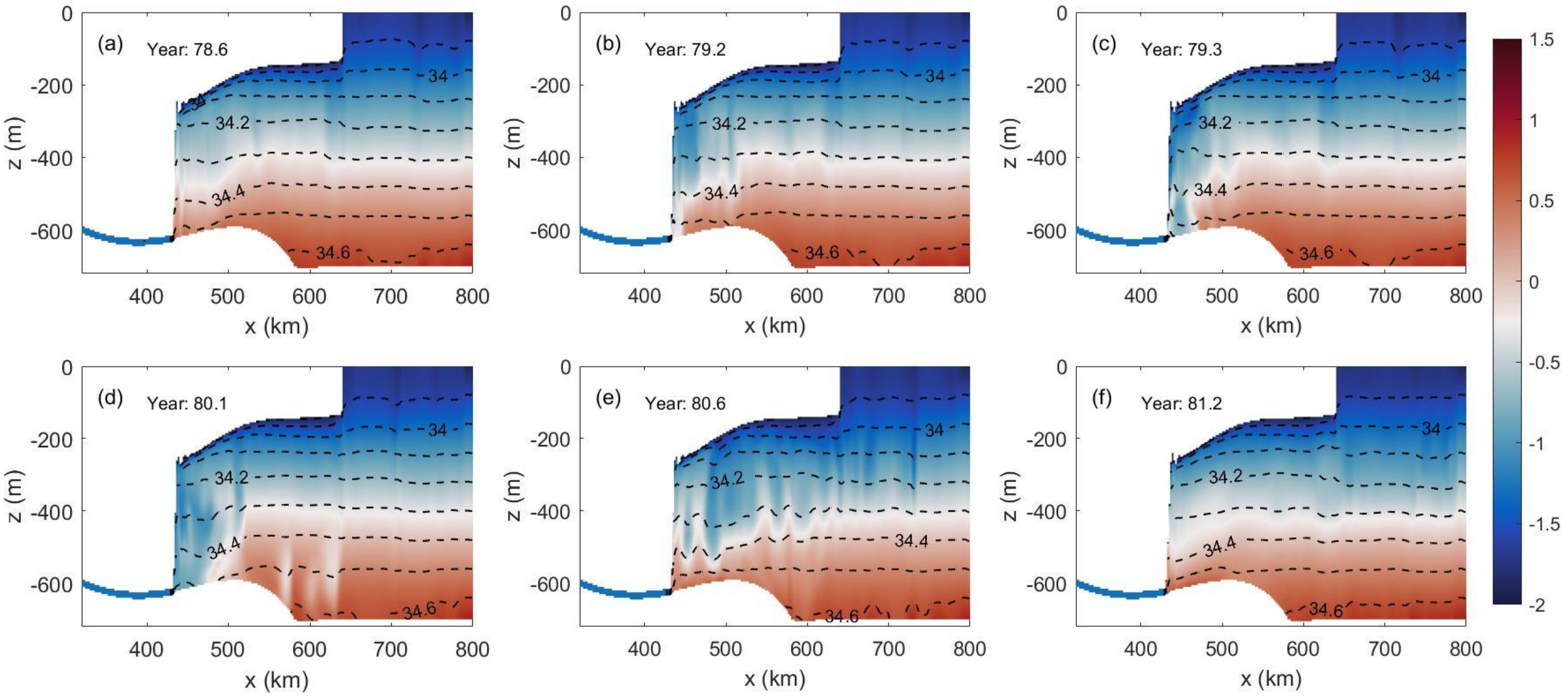
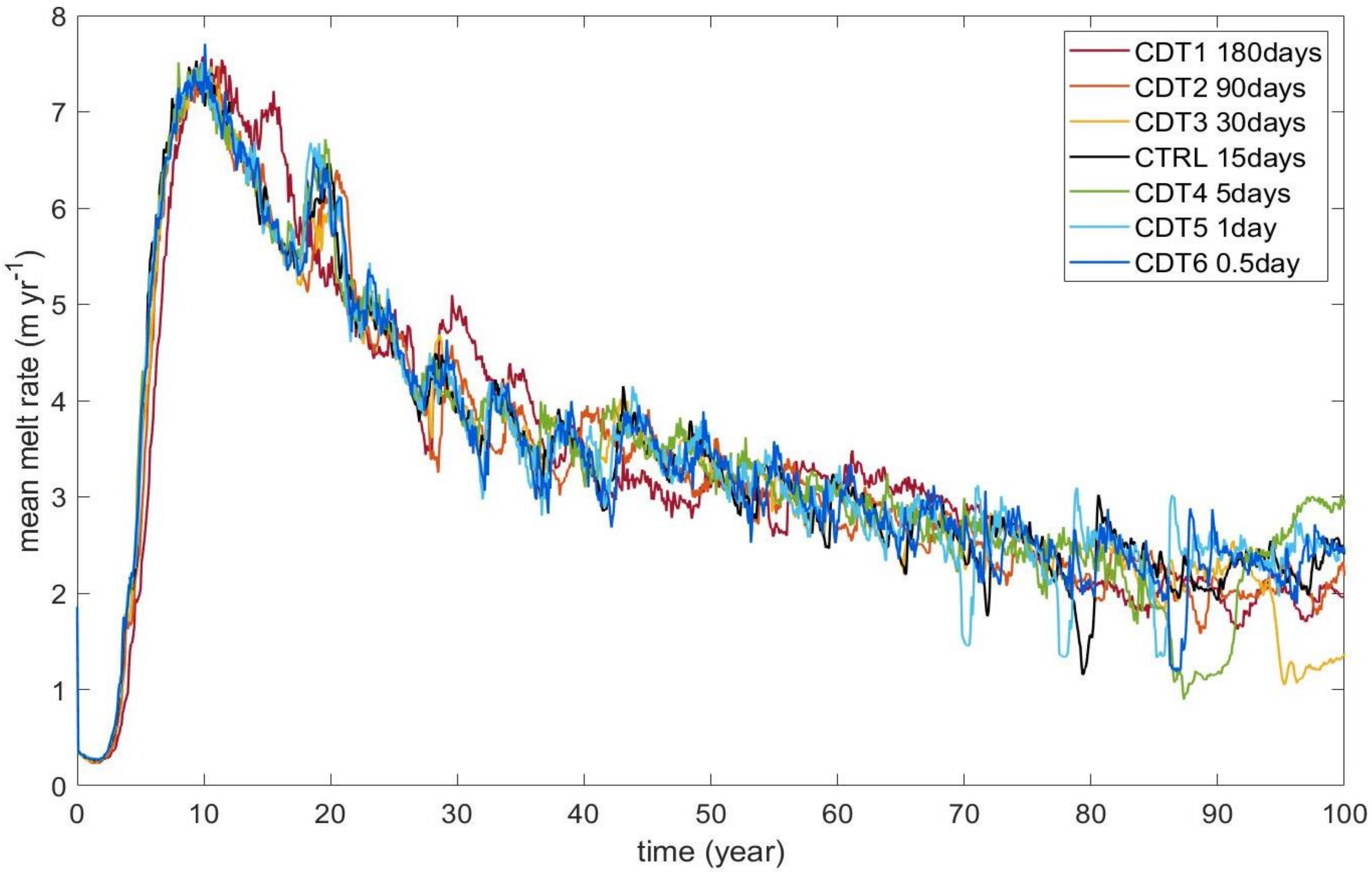
Oscillation pattern of the basal melting rate

- Cold-water-generation cycle was found around year 80 in CTRL



The XZ profiles of temperature and salinity at different years from CTRL. The (c) year 79.3 and (e) year 80.6 corresponds to the melt trough and peak.

Sensitivity to couple time intervals



The mean melt rates indicate very little sensitivity to the couple time interval between 0.5 days and 6 months in the general trend, which is consistent with the similar sensitivity tests using NEMO-Elmer/Ice (Favier et al., 2019) and POPSICLES (Asay-Davis et al., in prep).

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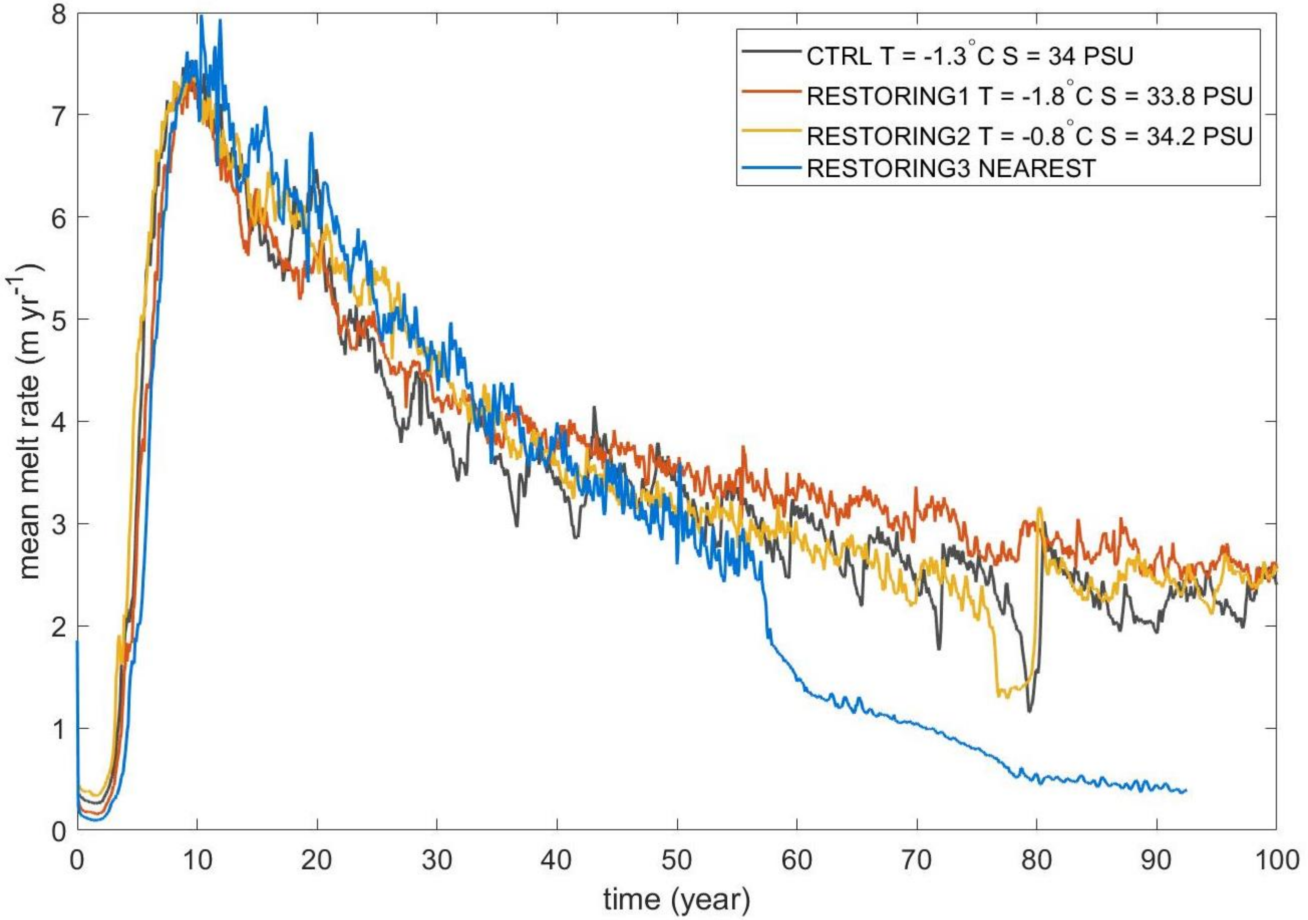
Sensitivity to tracer properties of restoring dry cells



- The tracer properties of restoring dry cells did not affect the basal melting and melt oscillation much.
- The reason behind the rapid decrease around year 57 in RESTORING3 is still unknown.

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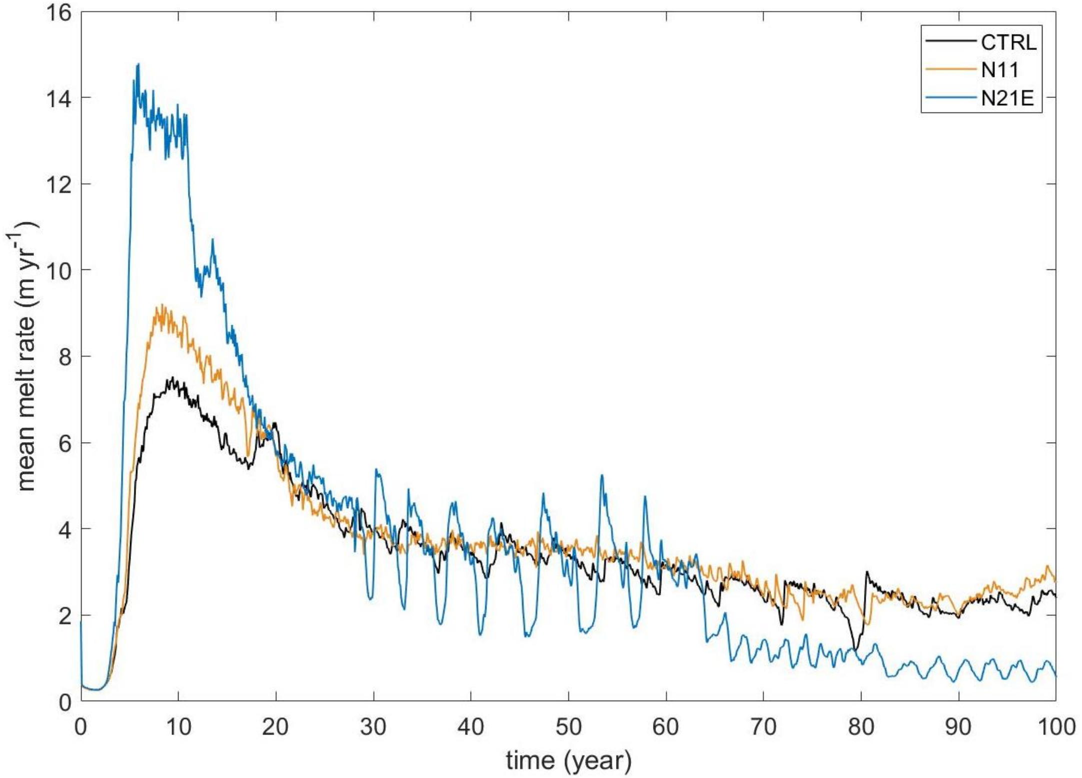
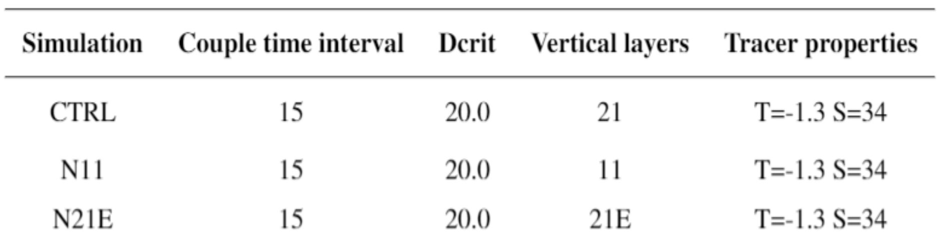
Sensitivity to vertical resolution in ocean model



- Finer resolution near the GL has lower melting, which has been explained in Gwyther et al. (2020)
- N21E exaggerated the oscillation from year 30, similar to the cold-water-generation cycle in the CTRL and likely related with instability events triggered during the ungrounding process



Simulation	Couple time interval	Dcrit	Vertical layers	Tracer properties
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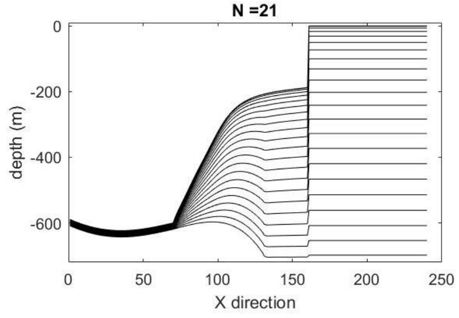
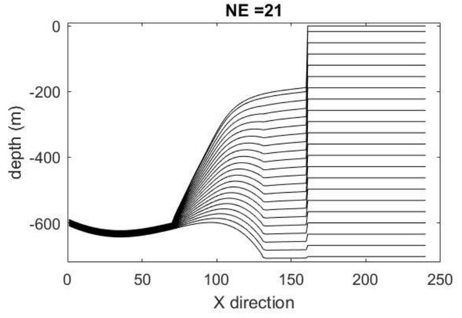
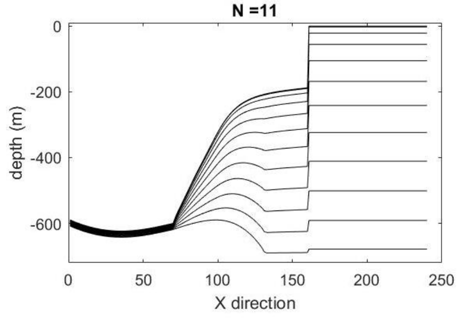
N21E	15	20.0	21E	T=-1.3 S=34







stratification

Thickness of 1st layer beneath the ice shelf for cell x =150:

- CTRL: 4.06 m
- N11 : 13.54 m
- N21E: 25.10 m

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Summary

- Non-linear combination of factors and potential threshold behaviour can have a significant impact on the basal melting
- Basal melting in the couple system is less sensitive to the couple time interval and the tracer properties of the restoring dry cells.
- Row-by-row ungrounding drives the melt oscillation in the couple system but how it triggers the melt oscillation is still unknown.
- The cold-water-generation cycle in CTRL and N21E might be caused by some non-physical instability events triggered during the ungrounding process.