G E U S

DTU

Influence of geothermal heat flux variations on Greenland Ice Sheet topography and dynamics

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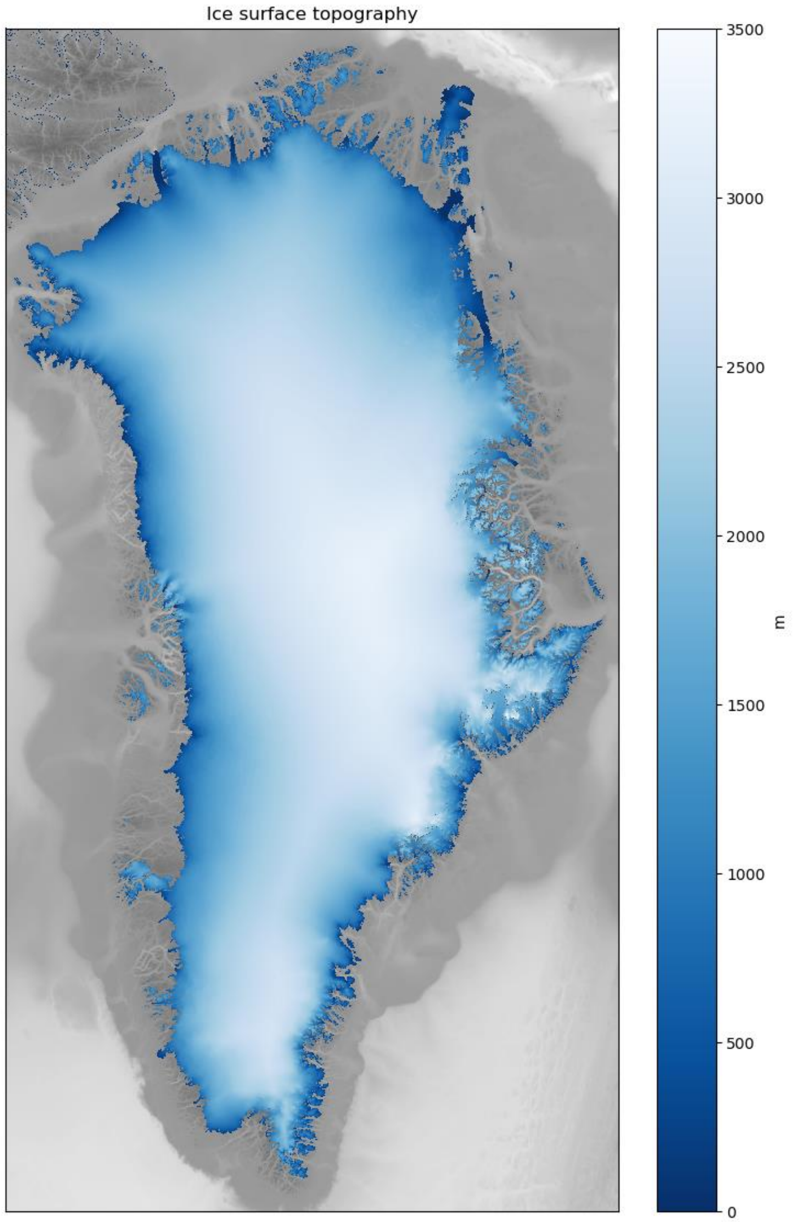
Present day ice surface topography (GIMP, Howat et al., 2014)

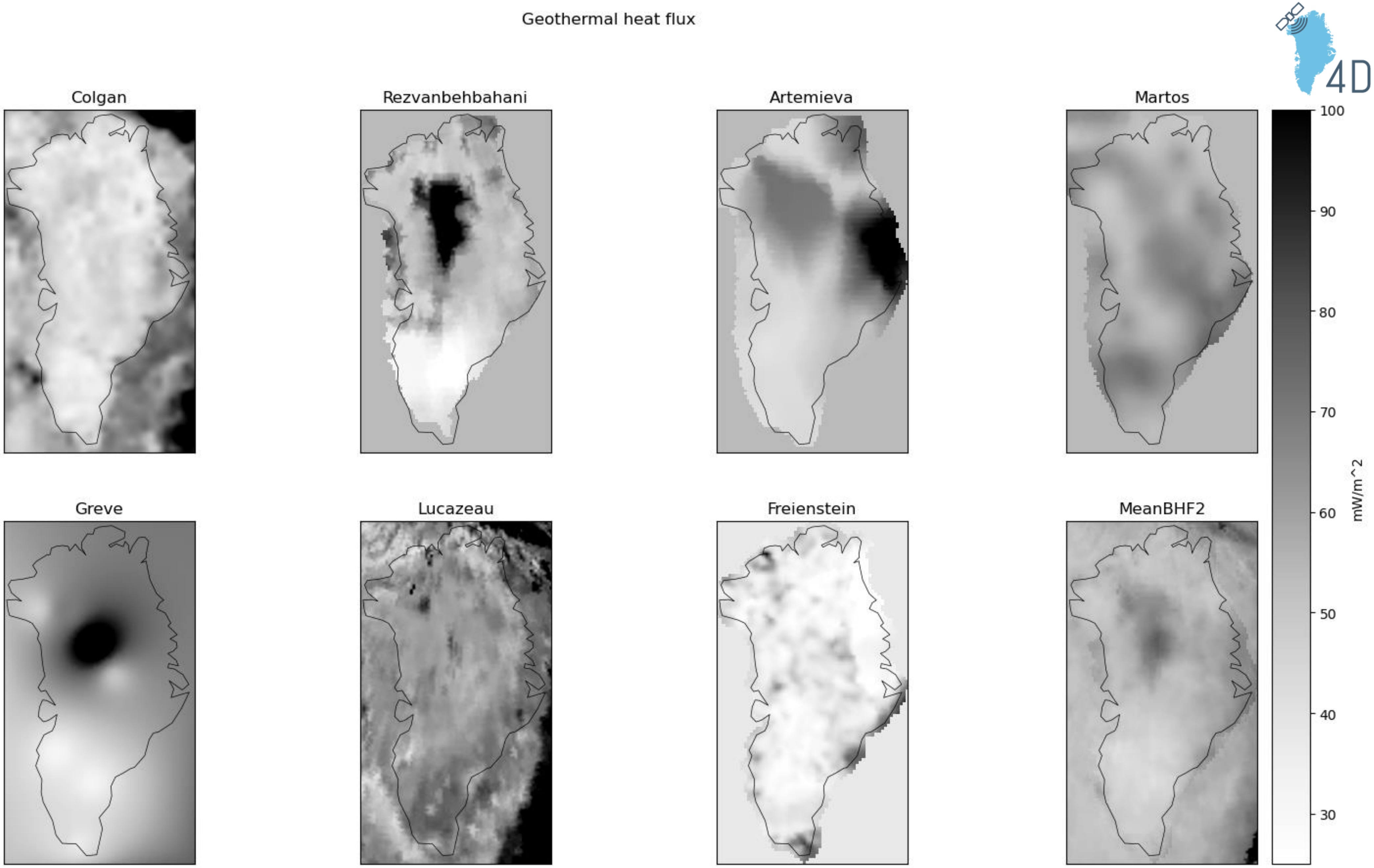


Model spin up

- Bedrock topography
- Ice surface topography
- Geothermal heat flux
- Climate forcings

Which geothermal heat flux field to use?

Training data for development of temperature emulator

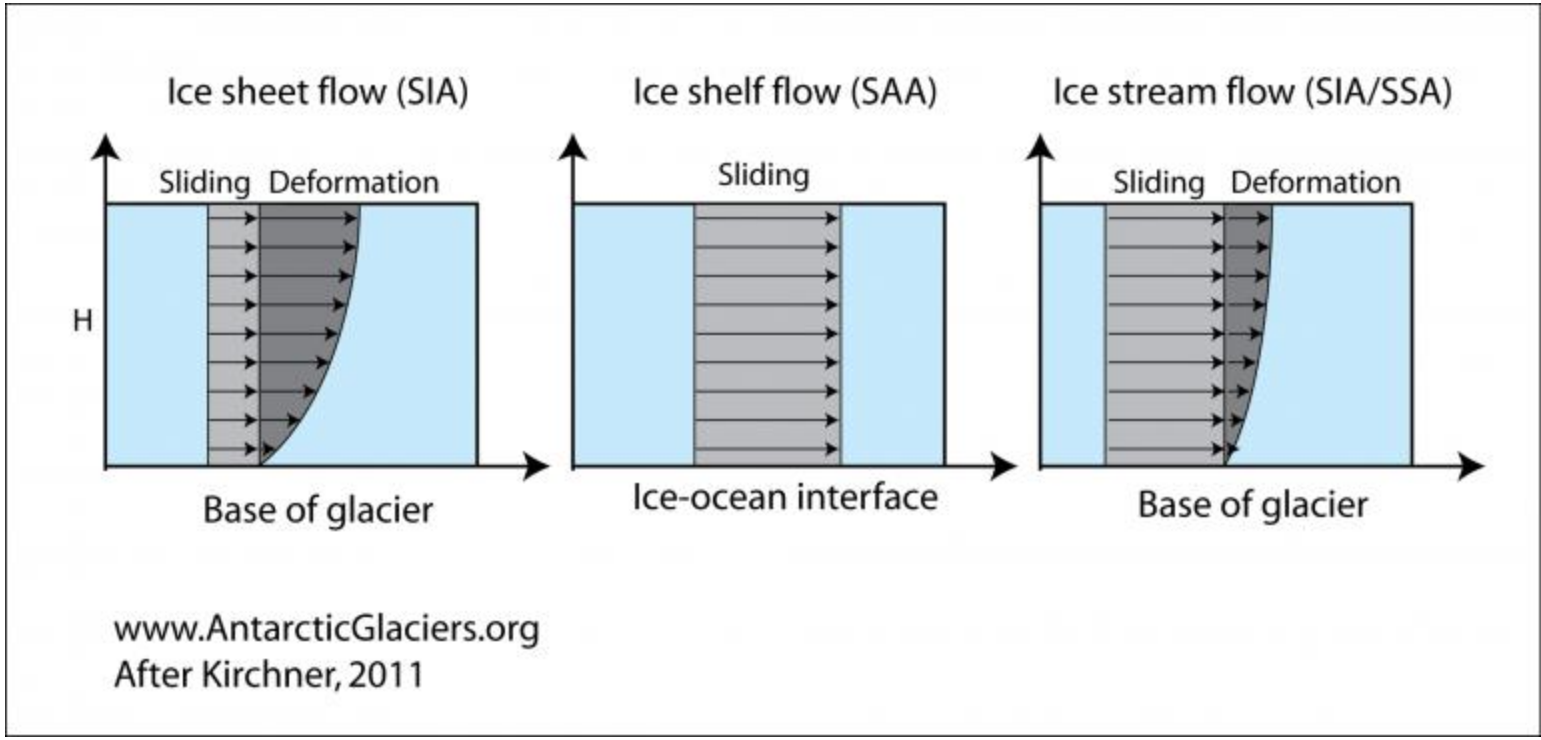


Colgan et al, 2022, Rezvanbehbahani et al. 2017, Artemieva 2019, Martos et al. 2018, Greve 2019, Lucazeau 2019, Freienstein pers. comm.

Model and setup

PISM
PARALLEL ICE SHEET MODEL

Shallow ice approximation combined with shallow shelf approximation to account for sliding.
Thermomechanically coupled, so ice viscosity changes with ice temperature.



Bed topography and ice surface topography from BedMachinev5
Present day climate: SeaRISE, Ettema et al., GRL 2017
Sea level anomaly: SeaRISE, Imbrie et al., 2006
Temperature anomaly: SeaRISE, Johnsen et al., 1997
Various geothermal heat flux fields

Structure of simulations

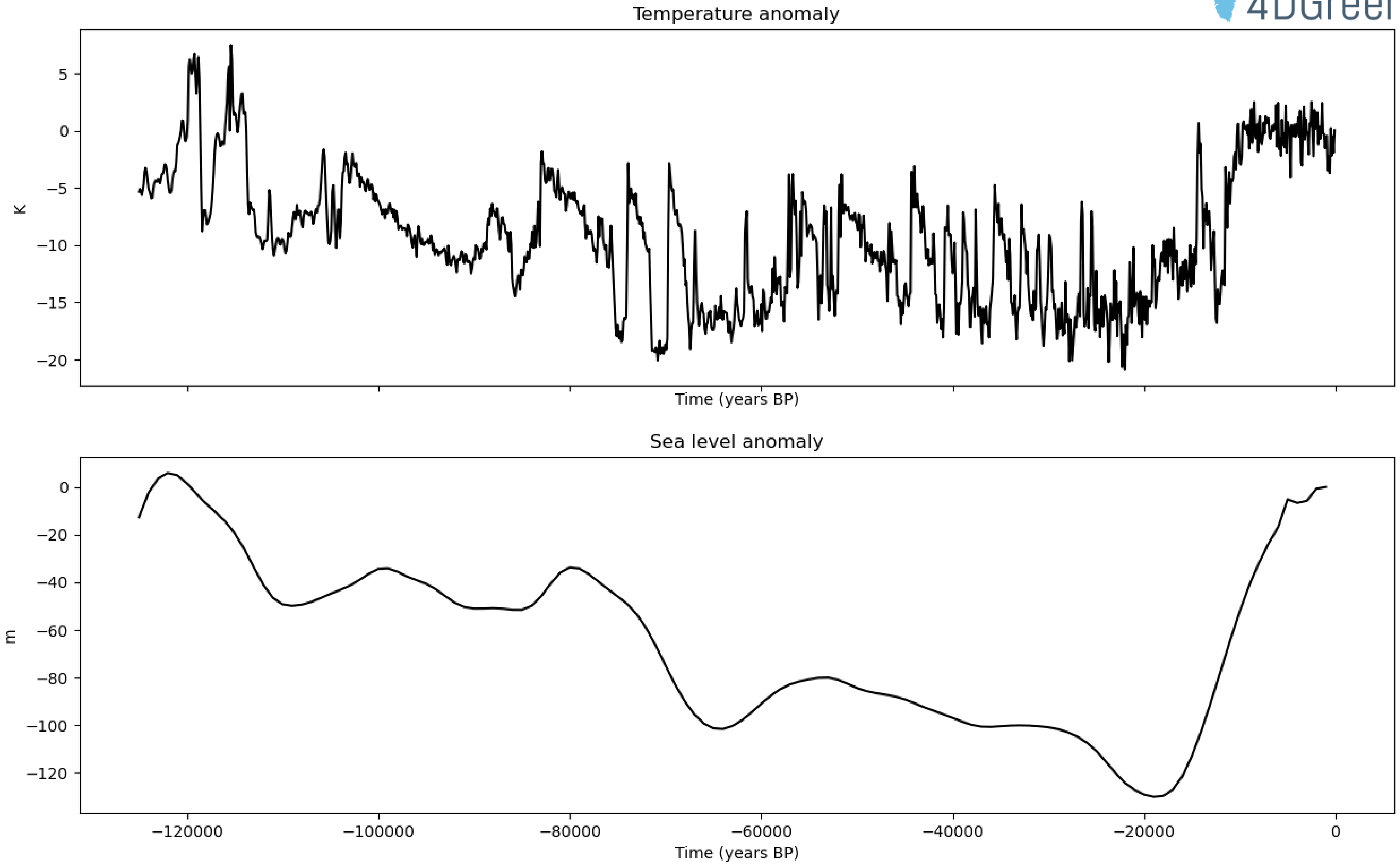
Constant climate runs

- Resolution effects
- Sensitivity

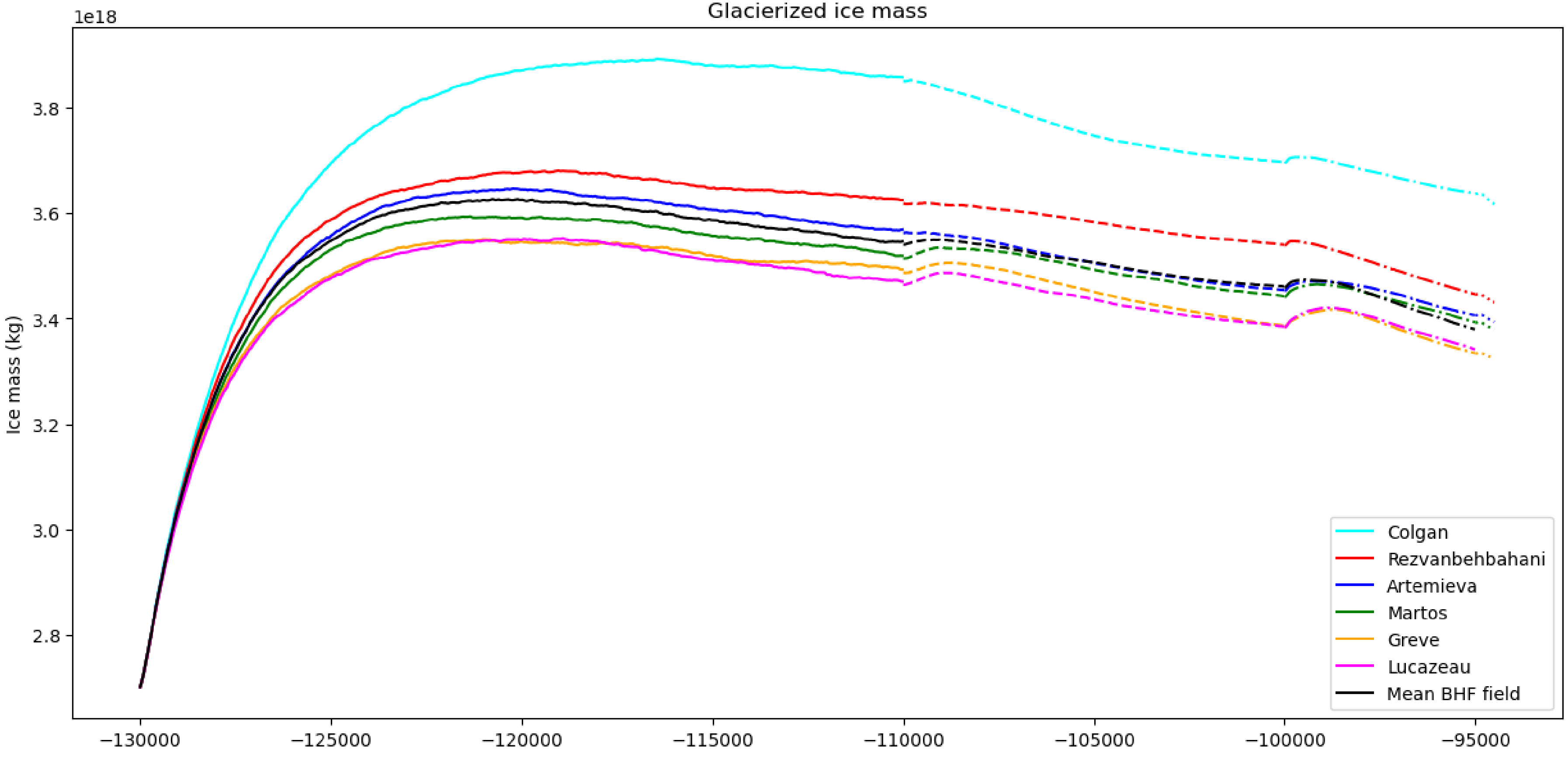
Paleo spinup (-125.000 years to present)

- Constant grid resolution of 10 km
- Sequence of increasing grid resolutions (20-10-5-2 km)

SeaRISE glacial cycle



Constant climate run, various geothermal heat flux fields



Largest ice mass:

Colgan: 3.64*10^18 kg (100%)

Rezvanbehbahani: 94.74%

Artemieva: 93.64%

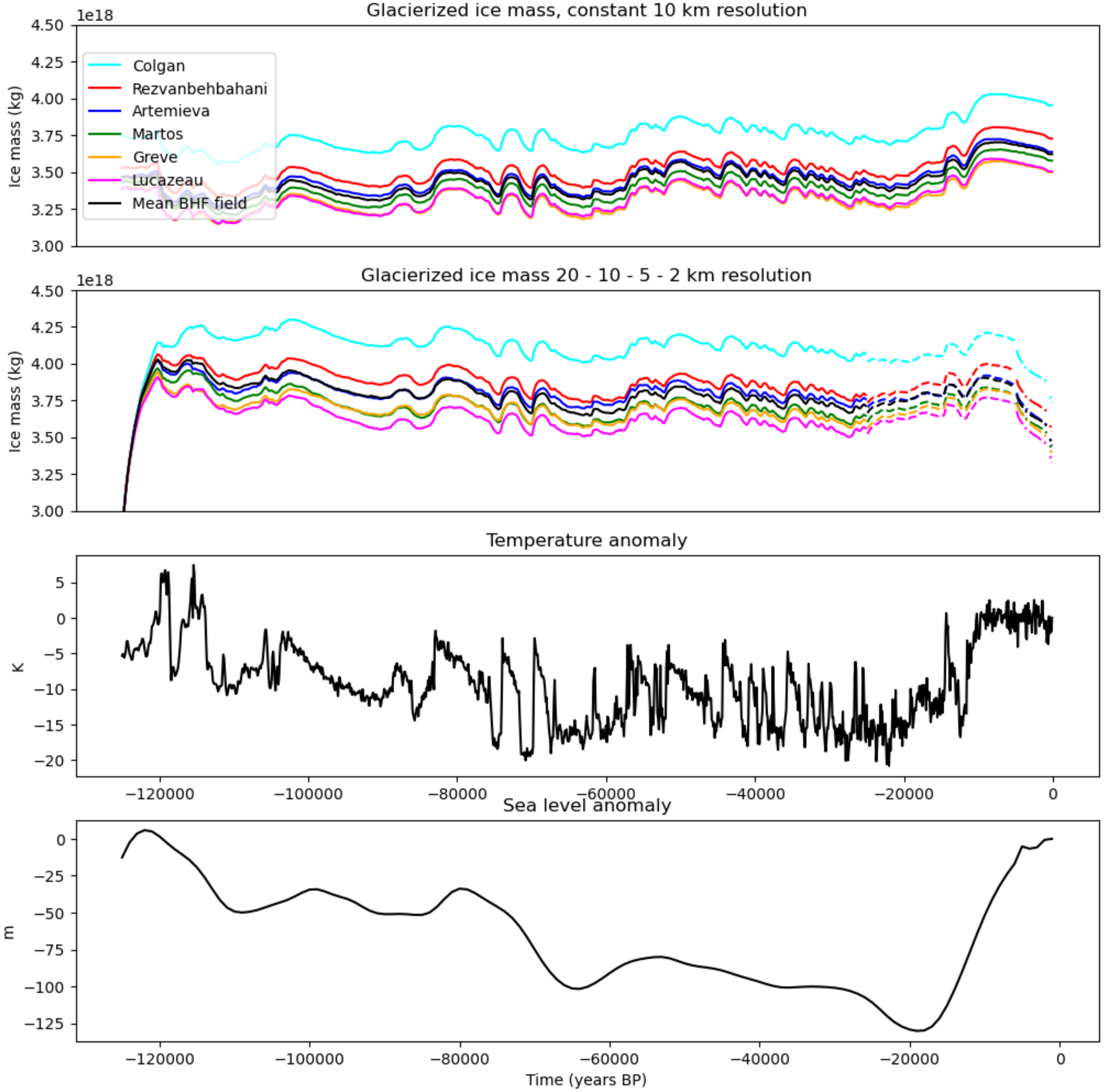
Martos: 93.28%

Greve: 91.66%

Lucazeau: 91.86%

Mean GHF field: 92.91%

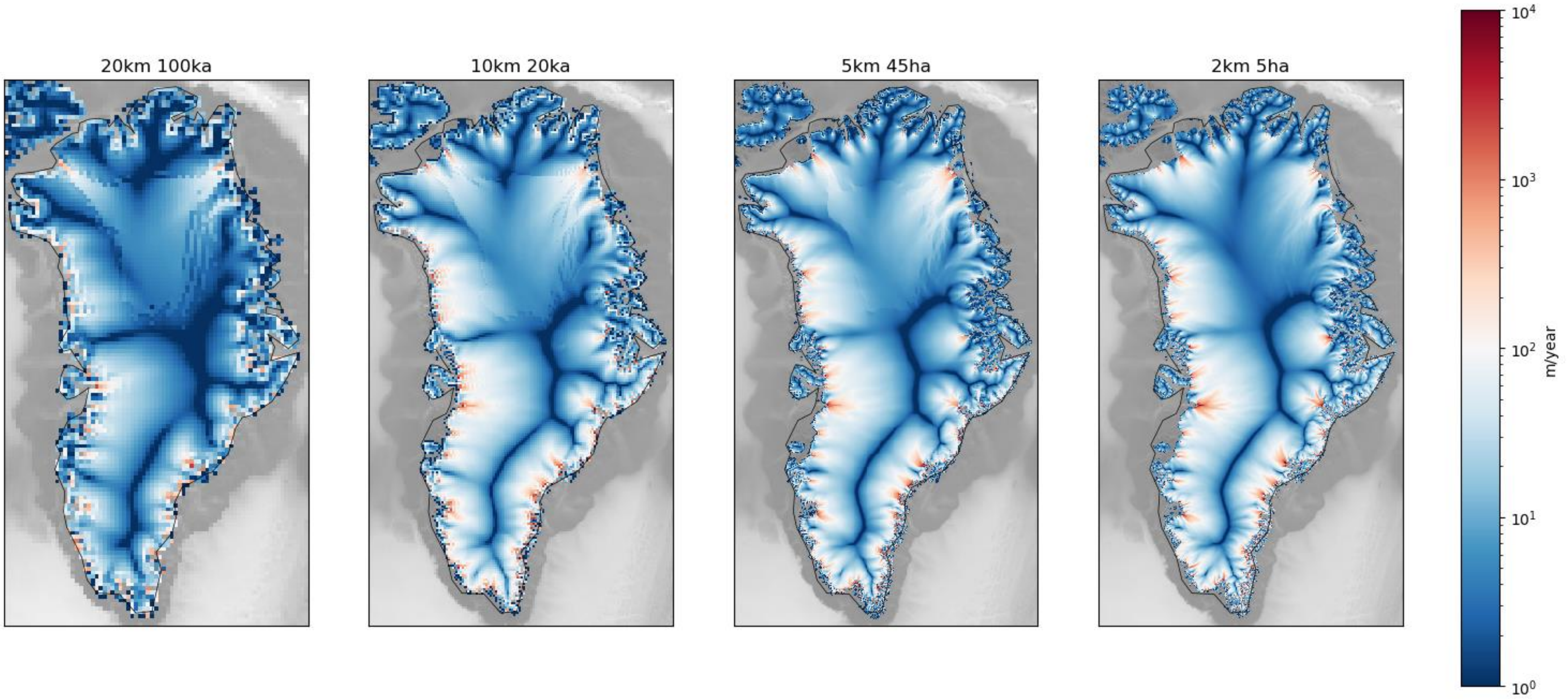
Total ice mass, glacial cycle runs

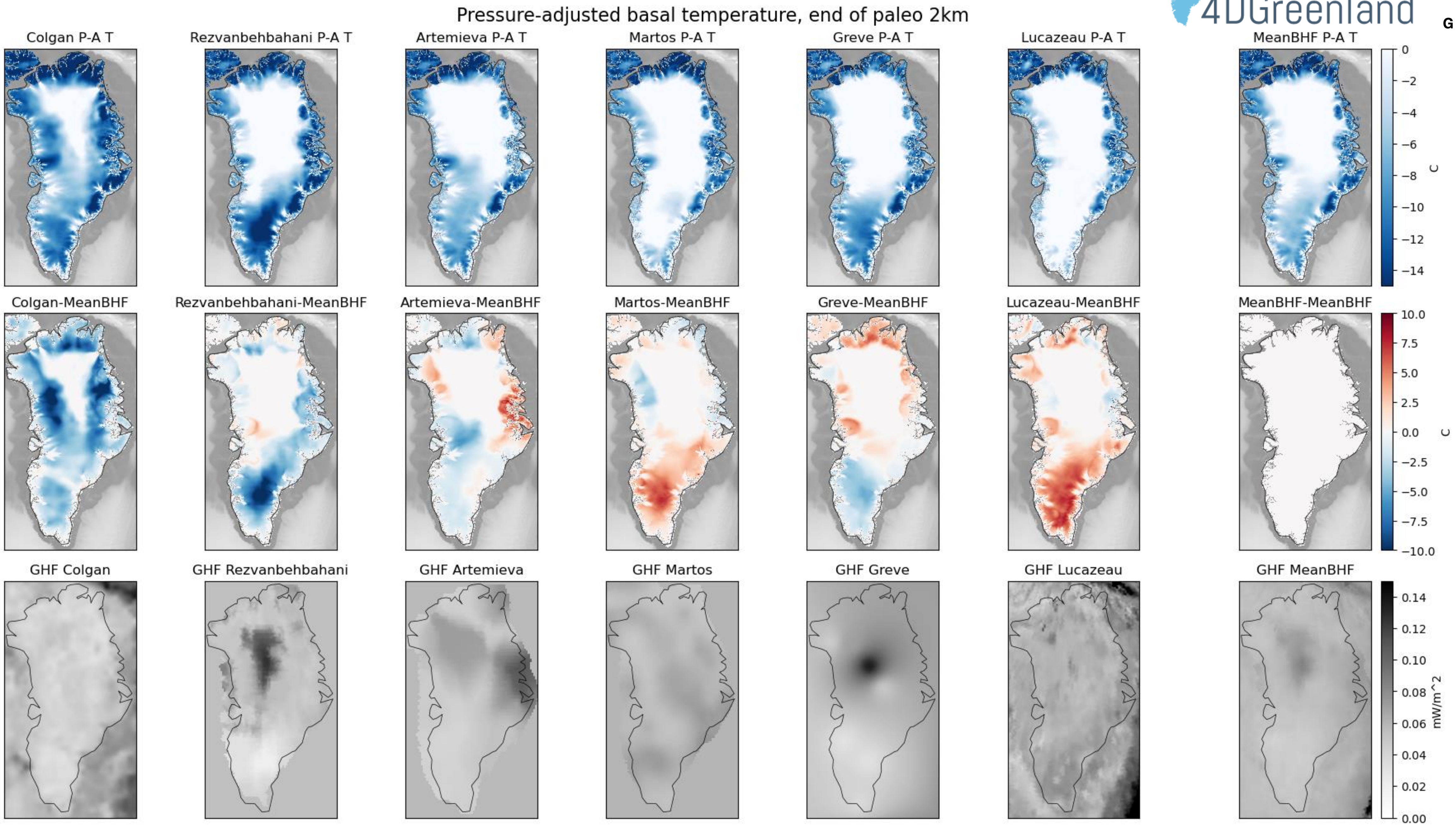


Largest ice mass (2 km):
Colgan 3.17*10^18 kg

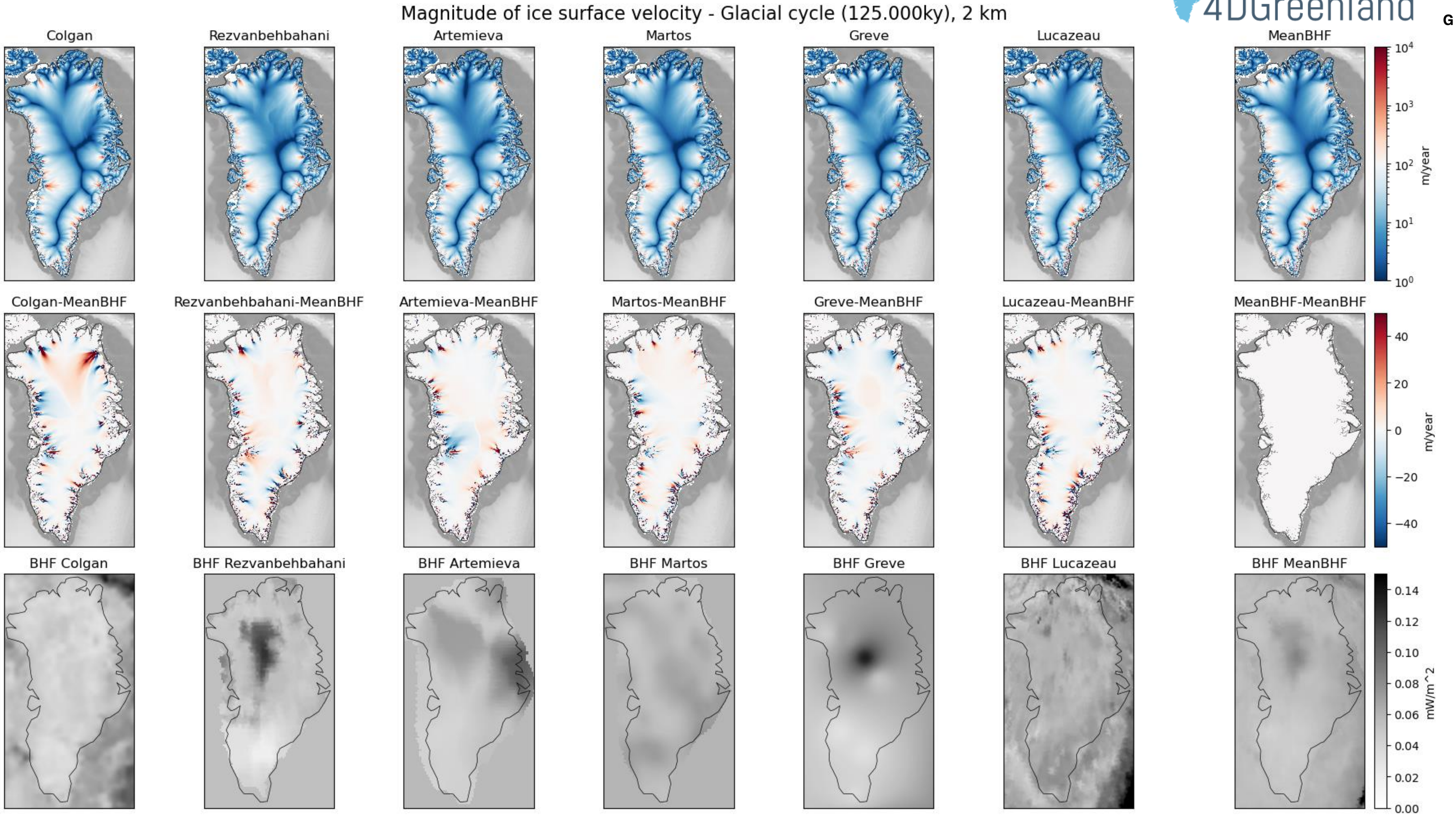
Rezvanbehbahani: 94.8%
Artemieva: 92.3%
Martos: 91.1%
Greve: 90.4%
Lucazeau: 89.2%
Mean BHF: 92.2%

Magnitude of surface velocity, paleo spinup, GHF MeanBHF



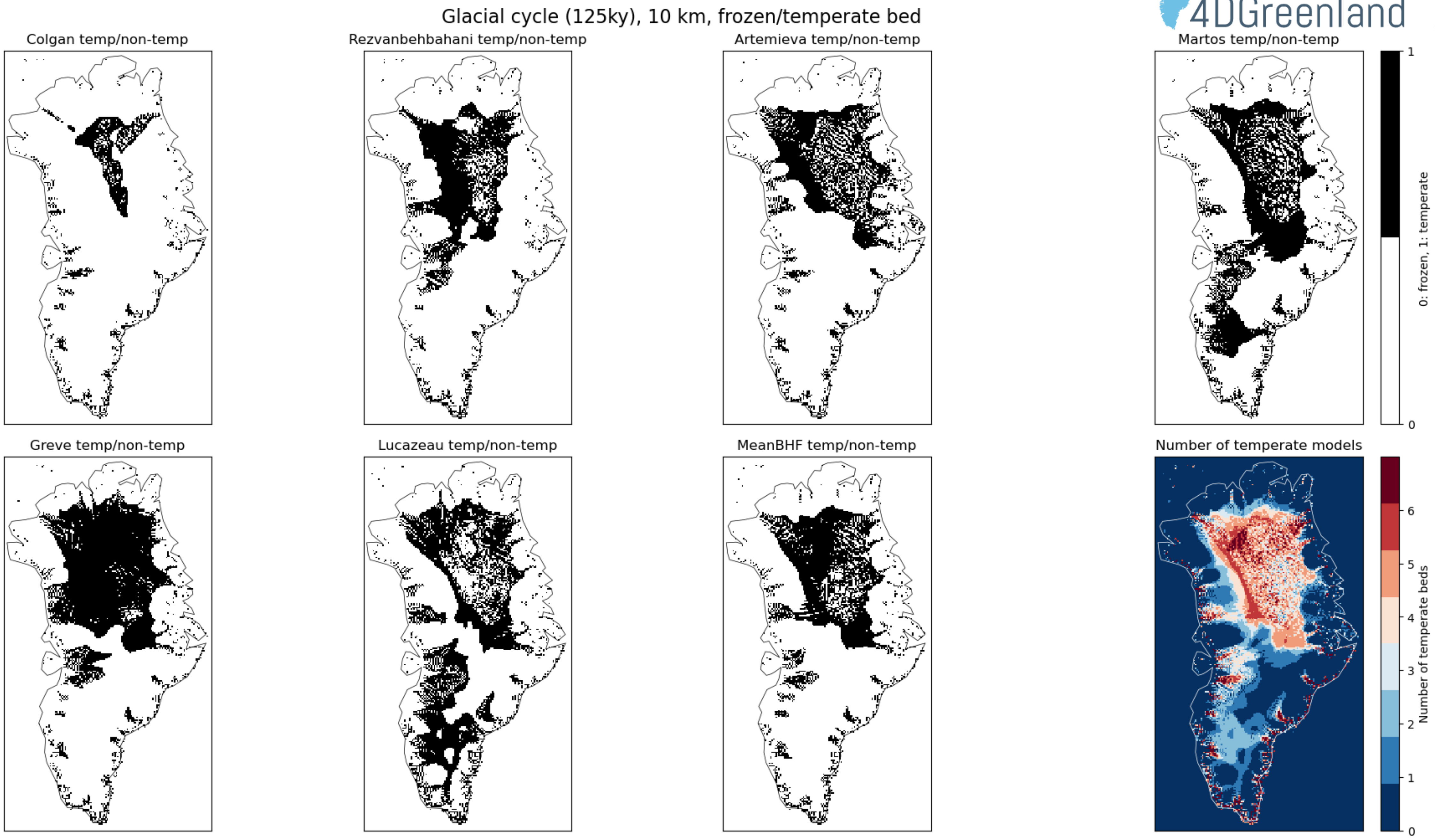


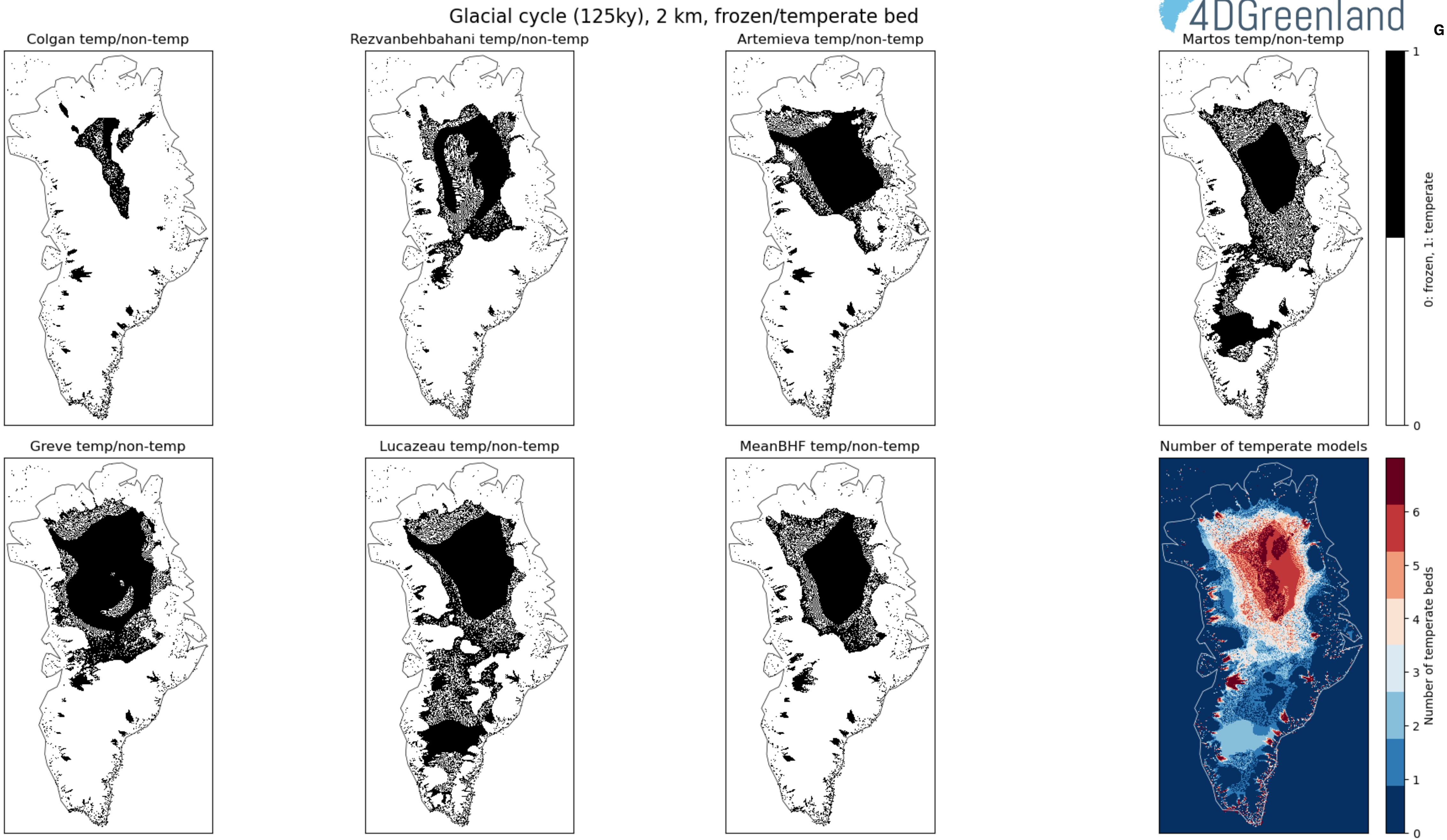
4DGreenland
GEUS



4DGreenland

G E U S


4DGreenland
GEUS
Glacial cycle (125ky), 10 km, frozen/temperate bed
Colgan temp/non-temp
Rezvanbehbahani temp/non-temp
Artemieva temp/non-temp
Martos temp/non-temp
0: frozen, 1: temperate
1
0
Greve temp/non-temp
Lucazeau temp/non-temp
MeanBHF temp/non-temp
Number of temperate models
Number of temperate beds
0
1
2
3
4
5
6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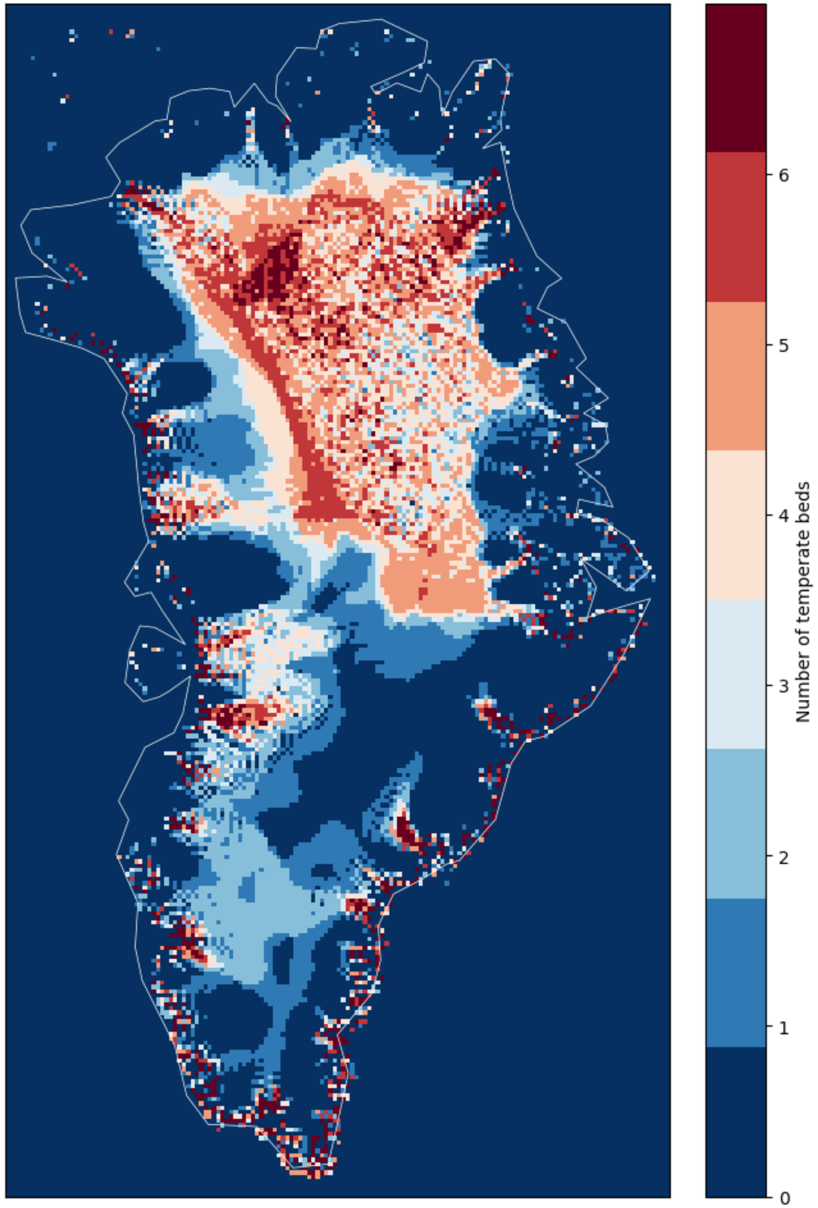
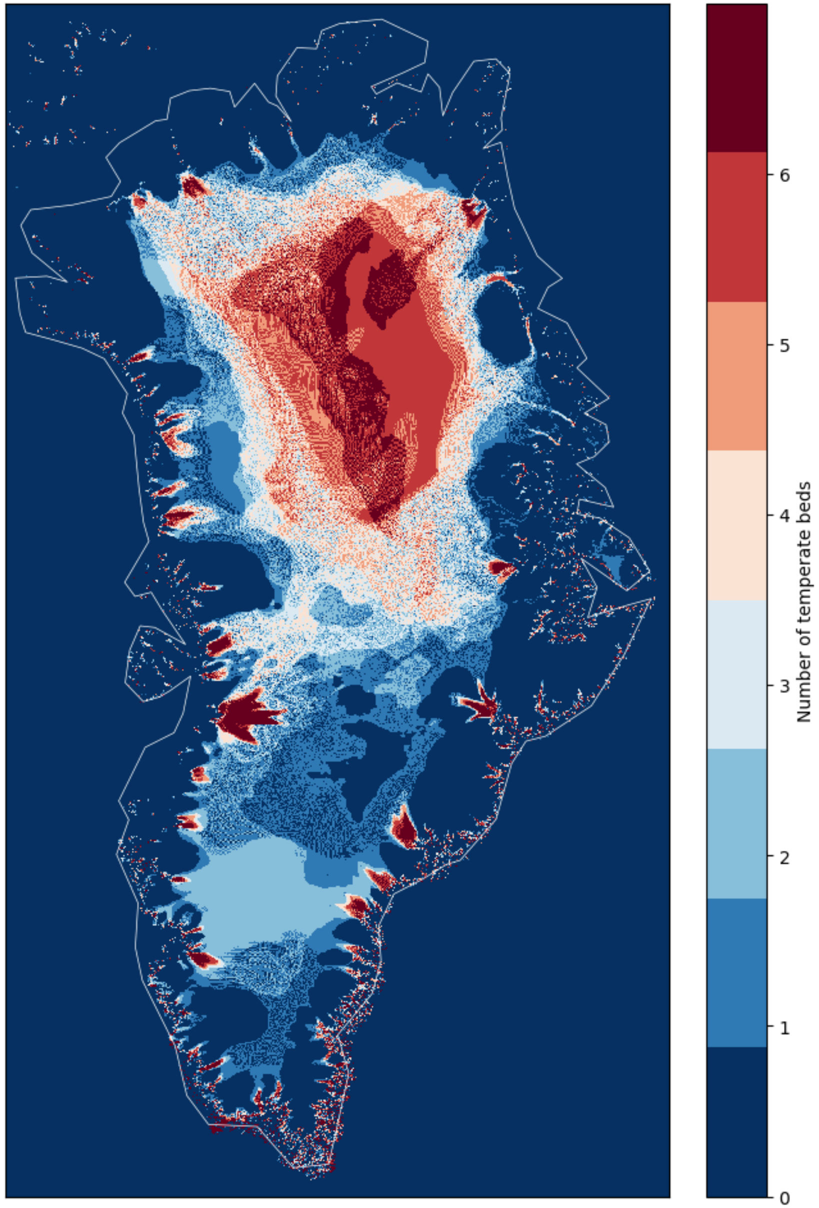
4DGreenland
GEUS

Number of models with temperate ice at bedrock 10 km



Number of models with temperate ice at bedrock 2 km



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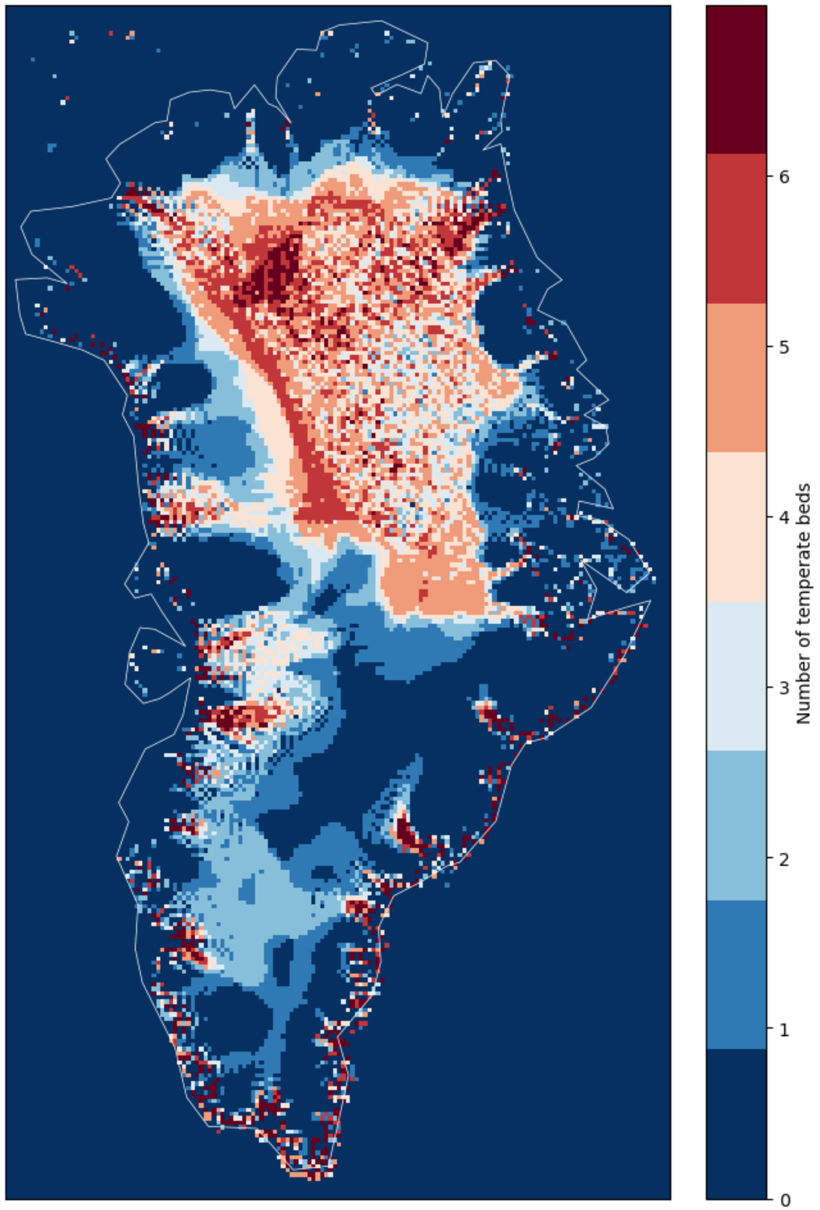
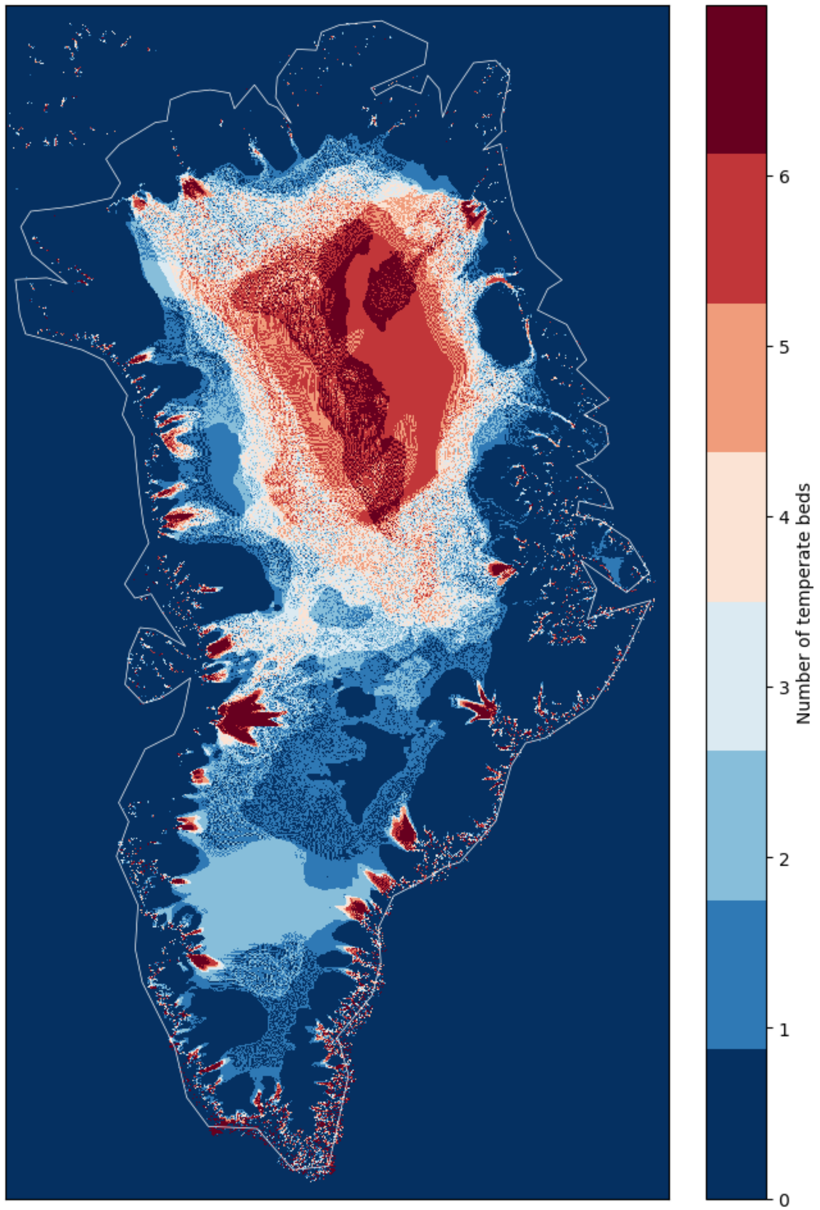
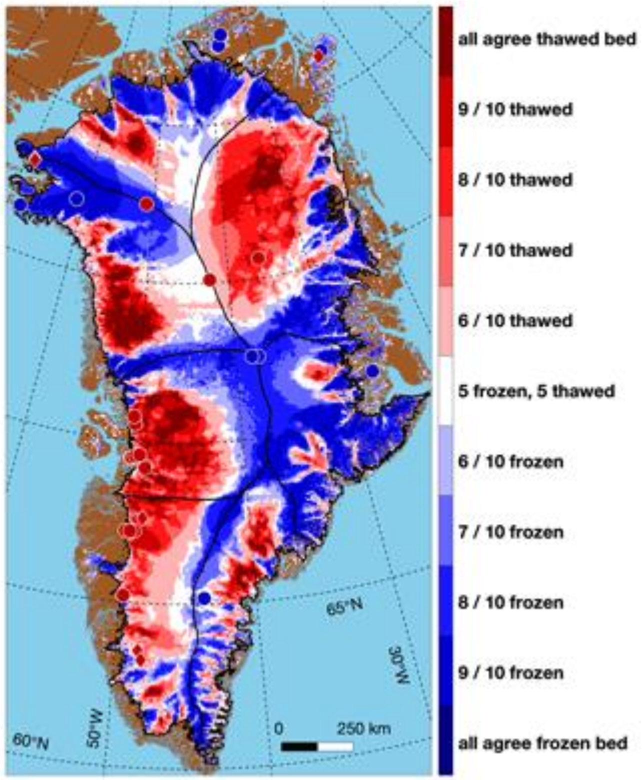


Number of models with temperate ice at bedrock 2 km



4DGreenland

GEUS

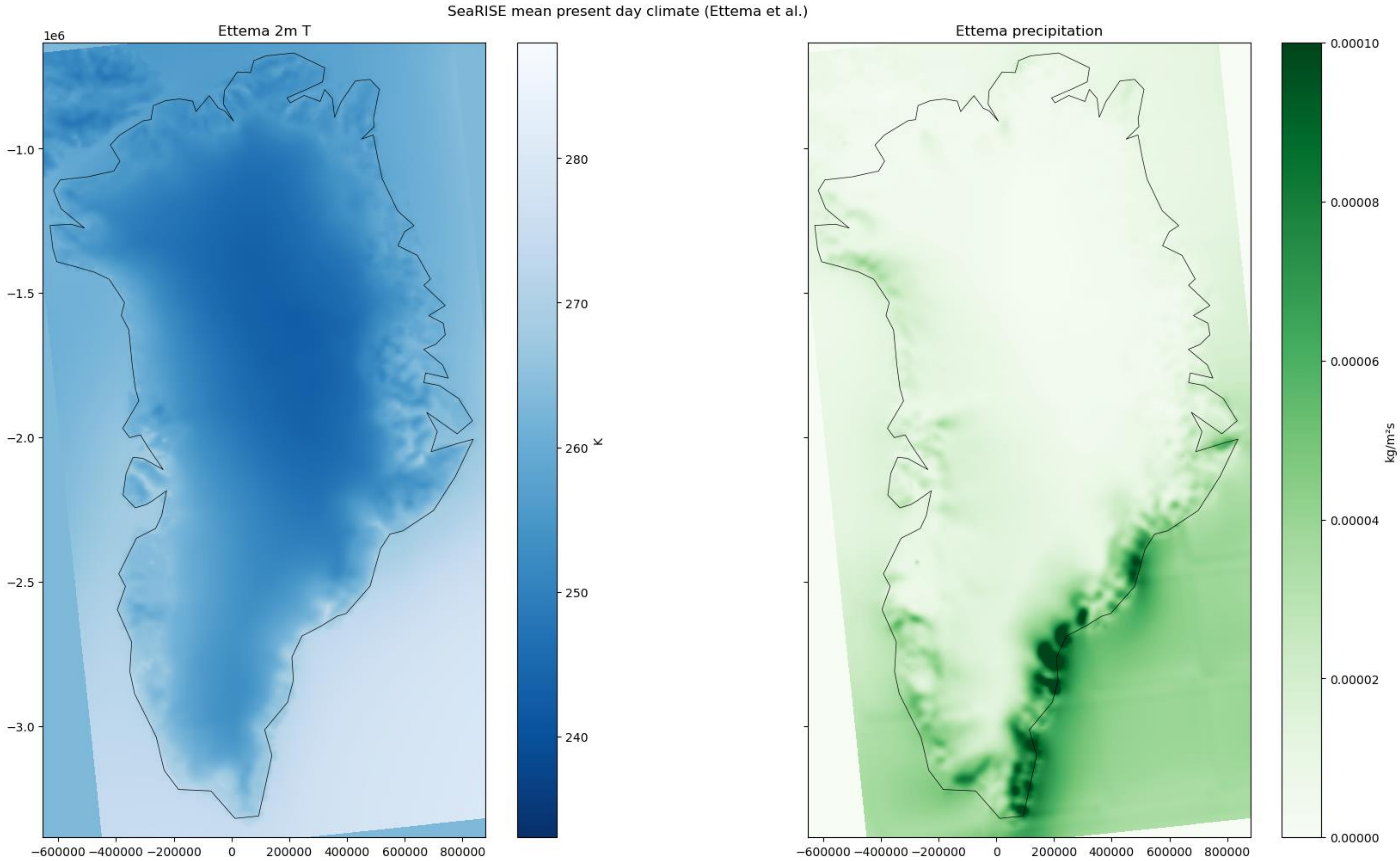


‘The basal thermal state (frozen or thawed) of the Greenland Ice Sheet is under-constrained due to few direct measurements, yet knowledge of this state is becoming increasingly important to interpret modern changes in ice flow.’

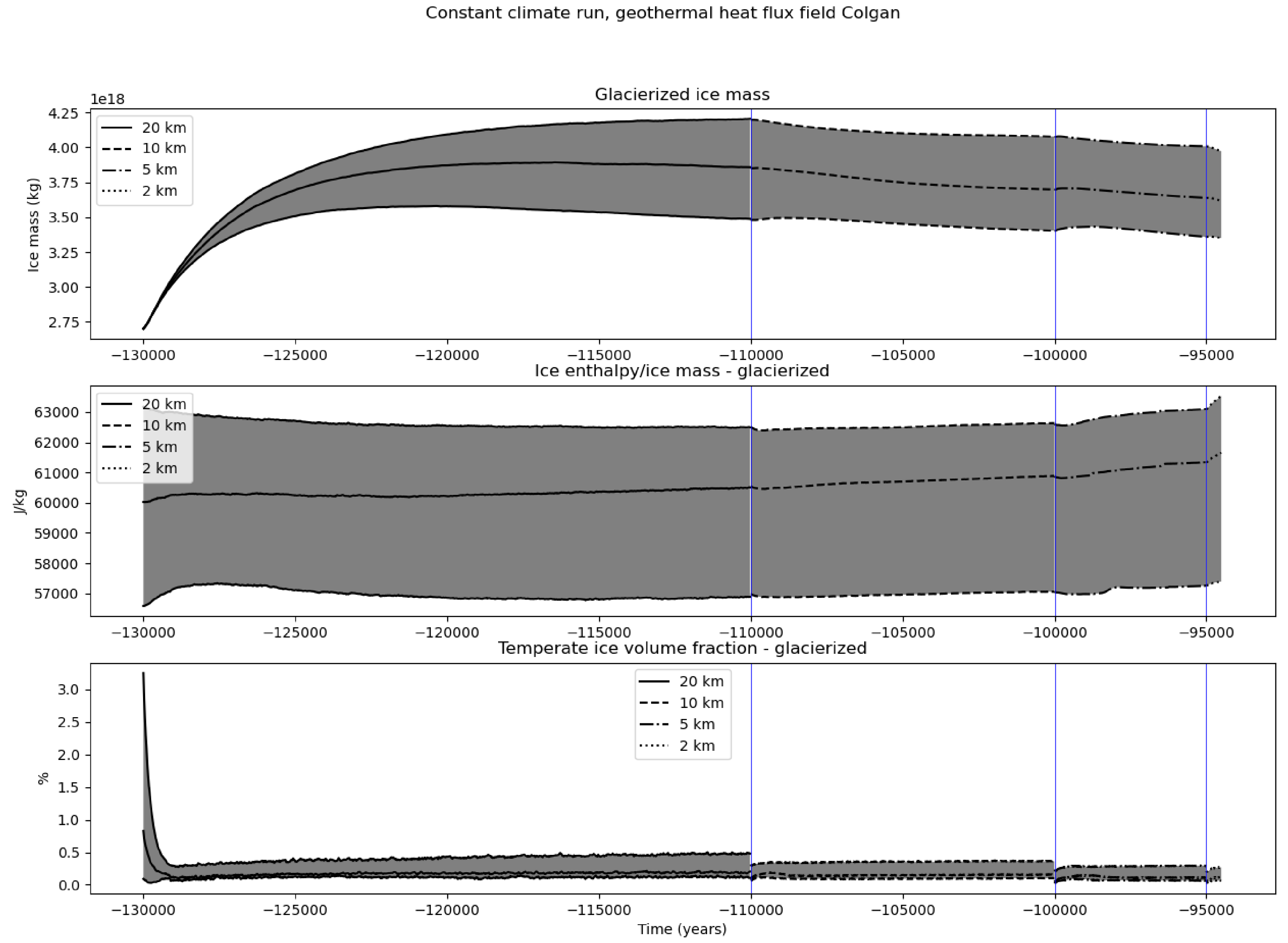
MacGregor et al., 2022

- **Geothermal heat flux matters.**
- **Spatial resolution matters.**
- **For projections of future ice mass loss, more realisations of the geothermal heat flux field should be included.**

GEOTHERMAL HEAT FLUX	TEMPERATE GRID CELLS 10 KM	TEMPERATE GRID CELLS 2 KM
COLGAN	10.09 %	8.84 %
REZVANBEHBAHANI	25.58 %	22.19 %
ARTEMIEVA	25.30 %	24.47 %
MARTOS	33.03 %	30.90 %
GREVE	36.41 %	32.68 %
LUCAZEAU	35.01 %	39.06 %
MEAN FIELD	26.11 %	24.97 %



SeaRISE mean present day climate (Ettema et al.)
Ettema 2m T
Ettema precipitation
1e6
−1.0
−1.5
−2.0
−2.5
−3.0
−600000 −400000 −200000 0 200000 400000 600000 800000
−600000 −400000 −200000 0 200000 400000 600000 800000
280
270
260
250
240
K
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
kg/m²s


Constant climate run, geothermal heat flux field Colgan
Glacierized ice mass
1e18
4.25
4.00
3.75
3.50
3.25
3.00
2.75
Ice mass (kg)
20 km
10 km
5 km
2 km
−130000
−125000
−120000
−115000
−110000
−105000
−100000
−95000
Ice enthalpy/ice mass - glacierized
63000
62000
61000
60000
59000
58000
57000
J/kg
20 km
10 km
5 km
2 km
−130000
−125000
−120000
−115000
−110000
−105000
−100000
−95000
Temperate ice volume fraction - glacierized
3.0
2.5
2.0
1.5
1.0
0.5
0.0
%
20 km
10 km
5 km
2 km
−130000
−125000
−120000
−115000
−110000
−105000
−100000
−95000
Time (years)