Idealized, high Resolution, 3D Modelling of Ice-Sheet Ocean interactions in long and narrow fjords

Jonathan Wiskandt[1,2], Inga Monika Koszalka[1], Jakob Nelsone[1], and Johan Nilsson[1]

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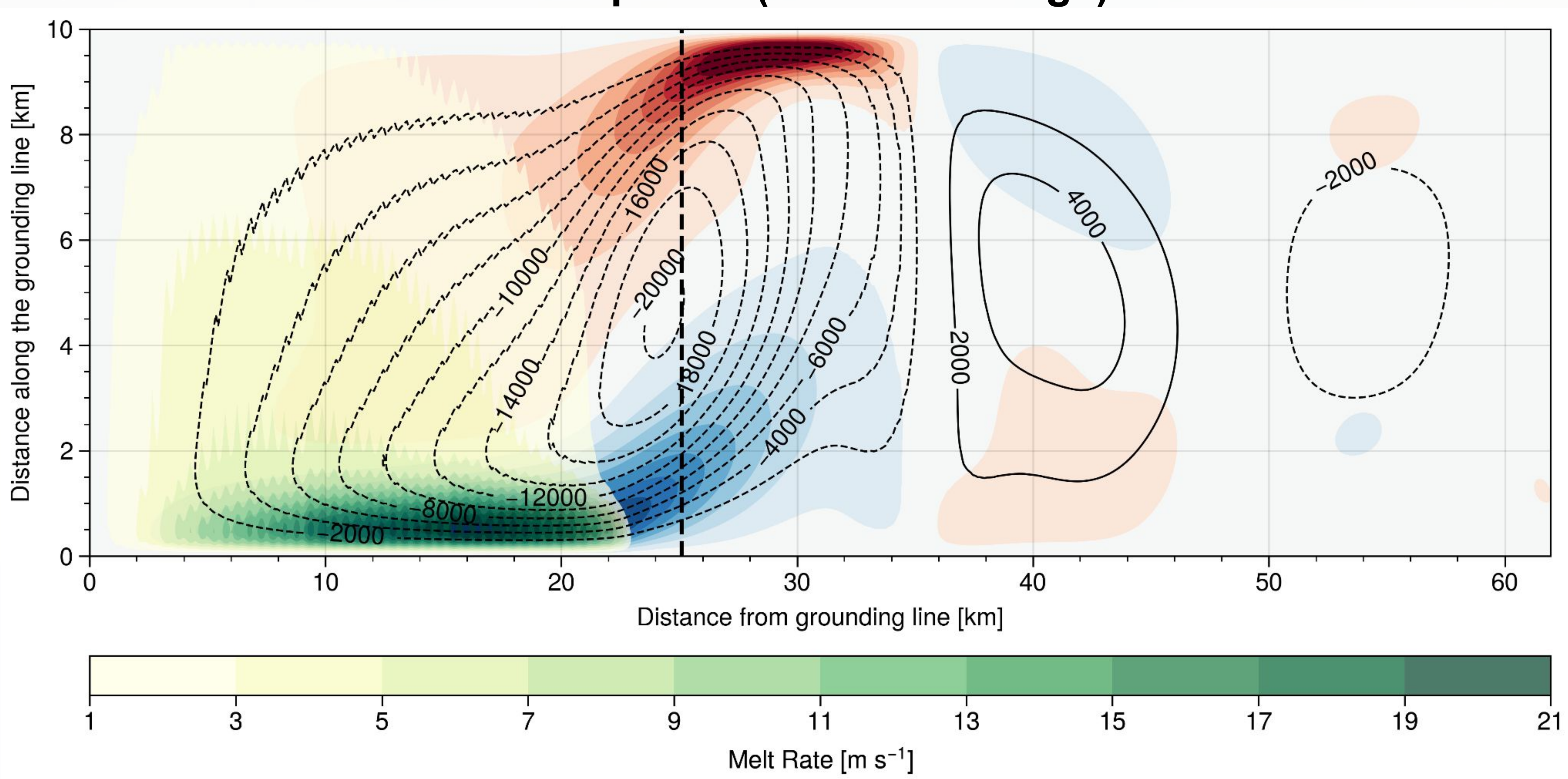
[2]Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

Non-uniform melt rate and circulation from 3-D Simulation

3-D: Top view (vertical average)



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This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

3-D simulations of Greenlandic fjords reveal unexpected basal melt patterns - even in narrow fjords.

3-D: Side view (across fjord average)

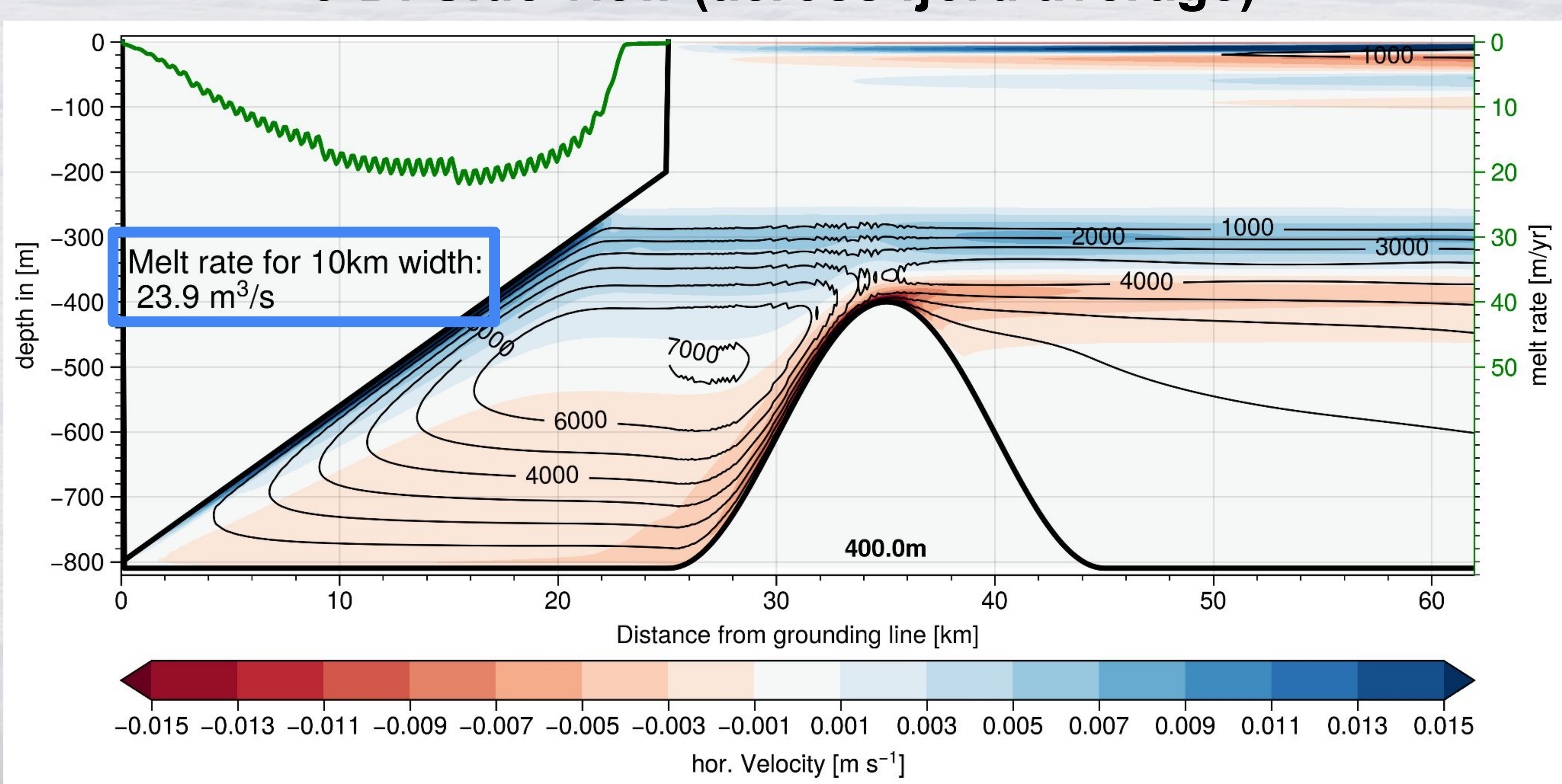


Figure 2: Side view 3-D simulation of a long and narrow Greenlandic fjord. Background colors and black contour lines as in figure 1. The green line shows the across-fjord maximum melt rate as a function of distance from the grounding line..

Corresponding 2-D simulation (non-rotating)

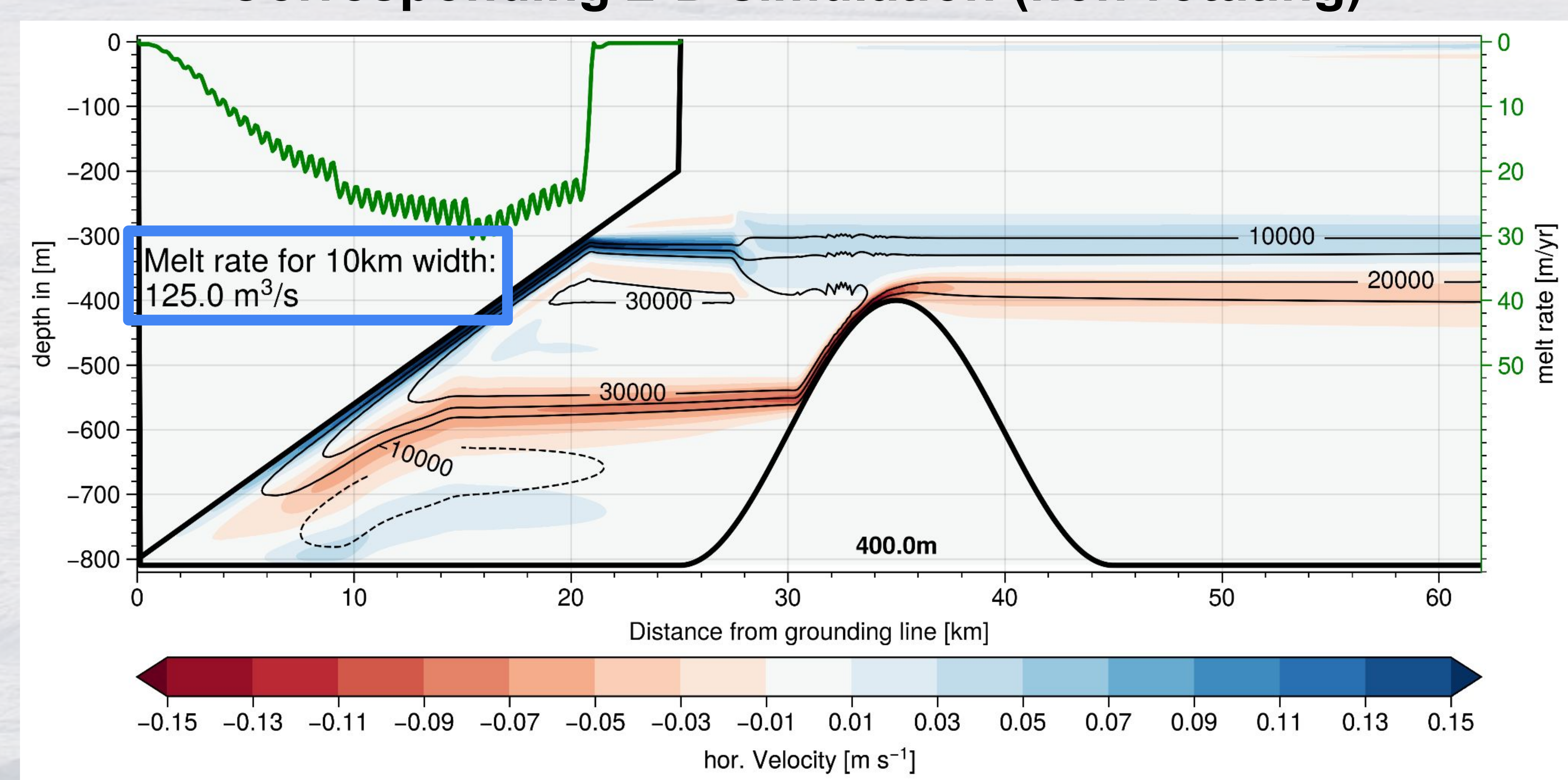


Figure 3: as Figure 2 but from a 2-D simulation

- ➔ small density difference between in- and out-flow leads to a small **Rossby Radius of ~2 km**
- ➔ **3-D simulations exhibit only 25% of the melt** of 2-D simulations (when assuming the same width)

- ➔ **Do we have to doubt the melt rates inferred from 2-D simulations?**
- ➔ **What are the implications for ice-sheet modeling?**

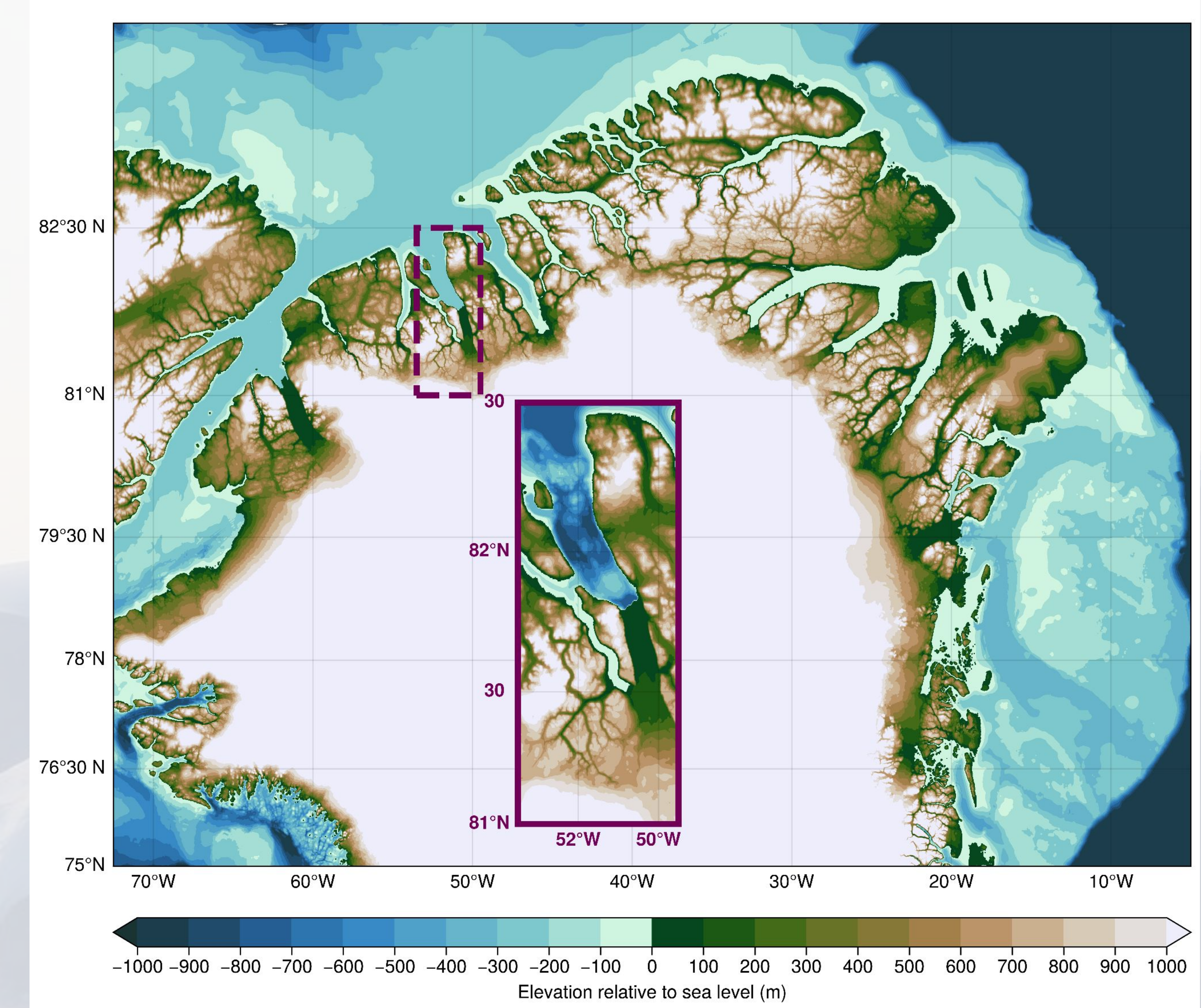


Figure 4: Bathymetric map of North Greenland and adjoining ocean. Inset shows a zoom in on Sherard Osborn fjord and the ice tongue of Ryder Glacier

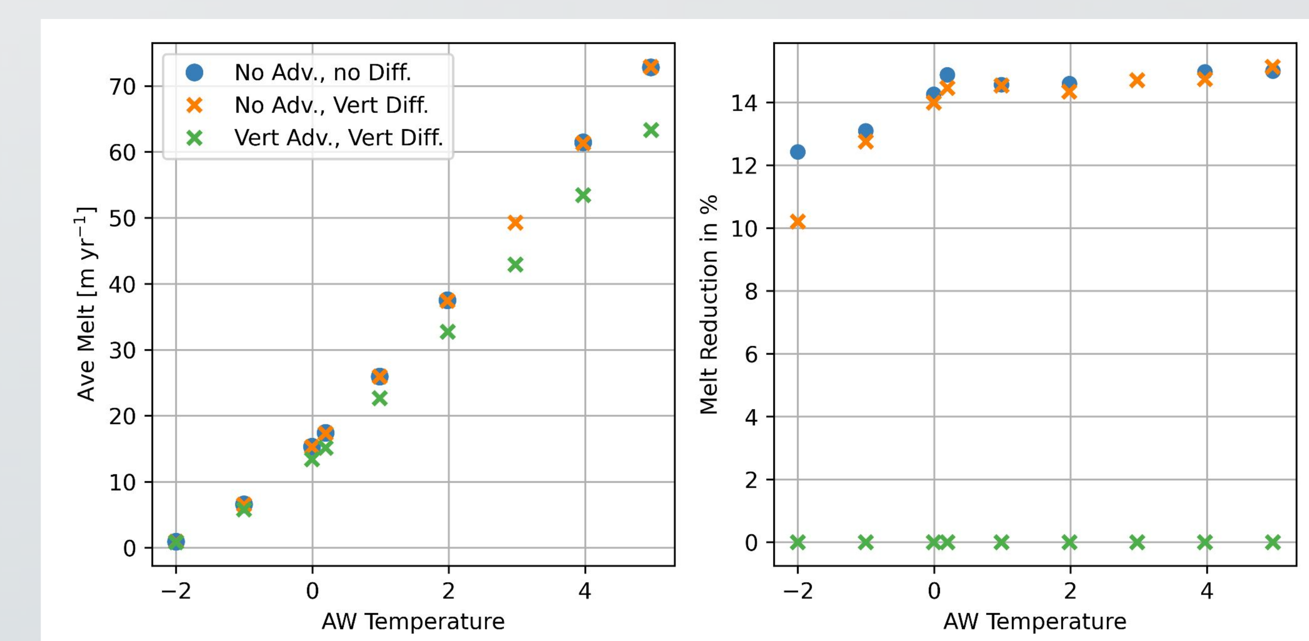
Background & Motivation

Ocean forcing of basal melt at the Greenland and Antarctic ice sheets remains a major source of uncertainty in climate ice sheet modelling. Previous efforts to represent the Greenlandic marine melt focused mainly on the properties of the ocean waters reaching the marine terminating glaciers as well as the near-ice boundary layer flows and processes at the ice-ocean interface. Most simulations of Greenlandic fjord are 2-D and across fjord variability is usually considered negligible. We show results from simulations based on measurements in Sherard Osborn Fjord in front of Ryder Glacier. The local Rossby radius of deformation is smaller 2 km (using the two layer approx.).

The Model:

- MITgcm, non-hydrostatic, rigid lid
- Resolution: dx = dy = 100m; dz = 3m
- Initial and Boundary condition from observations in Sherard Osborn Fjord in North Greenland
- 3-Equation Melt parametrization with melt dependent heat flux:

Melt dependent heat flux vs. **linear temperature gradient** vs. **no conduction**:



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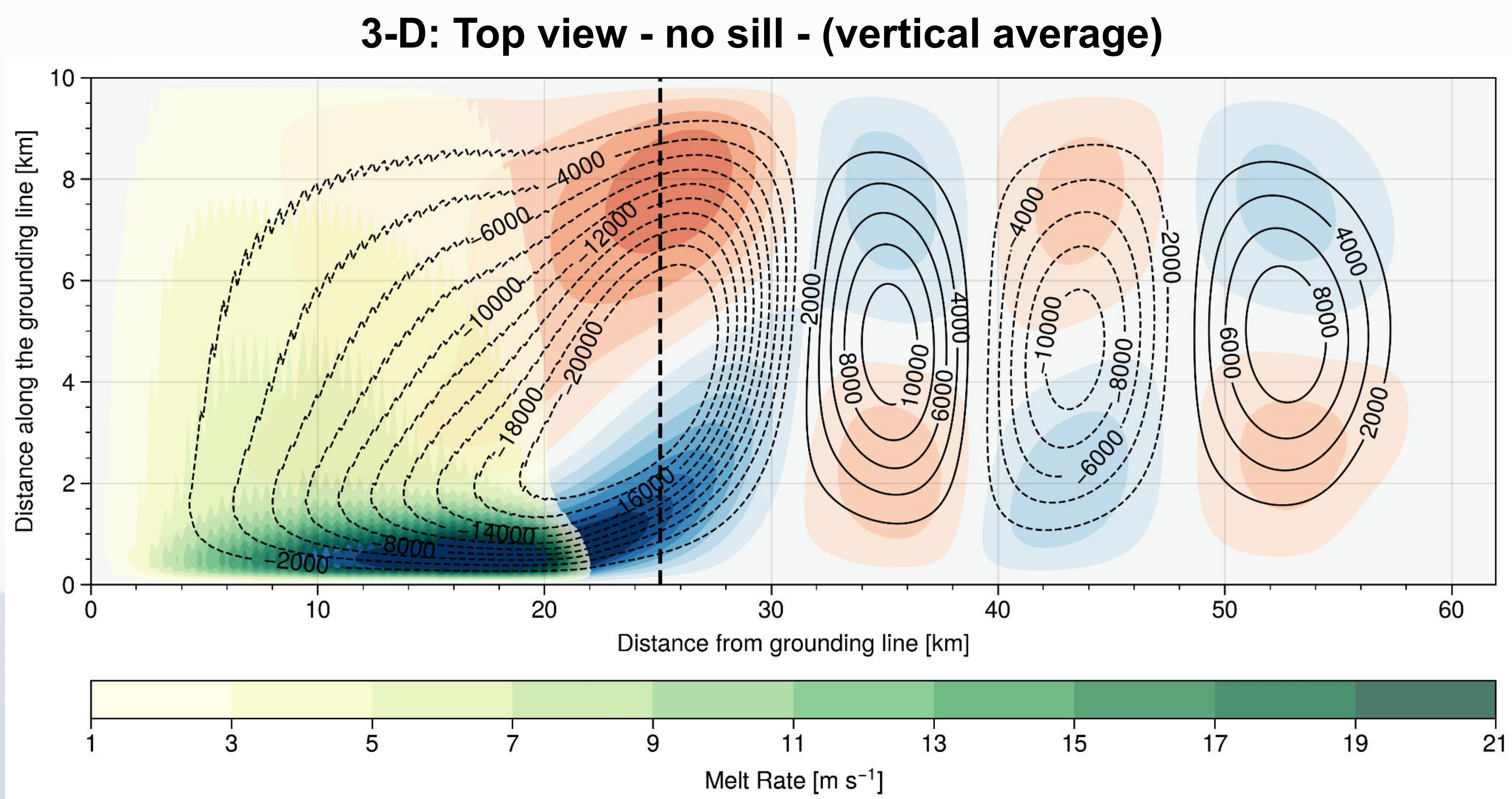

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3-D simulations of Greenlandic fjords **reveal unexpected circulation** patterns - even in narrow fjords.

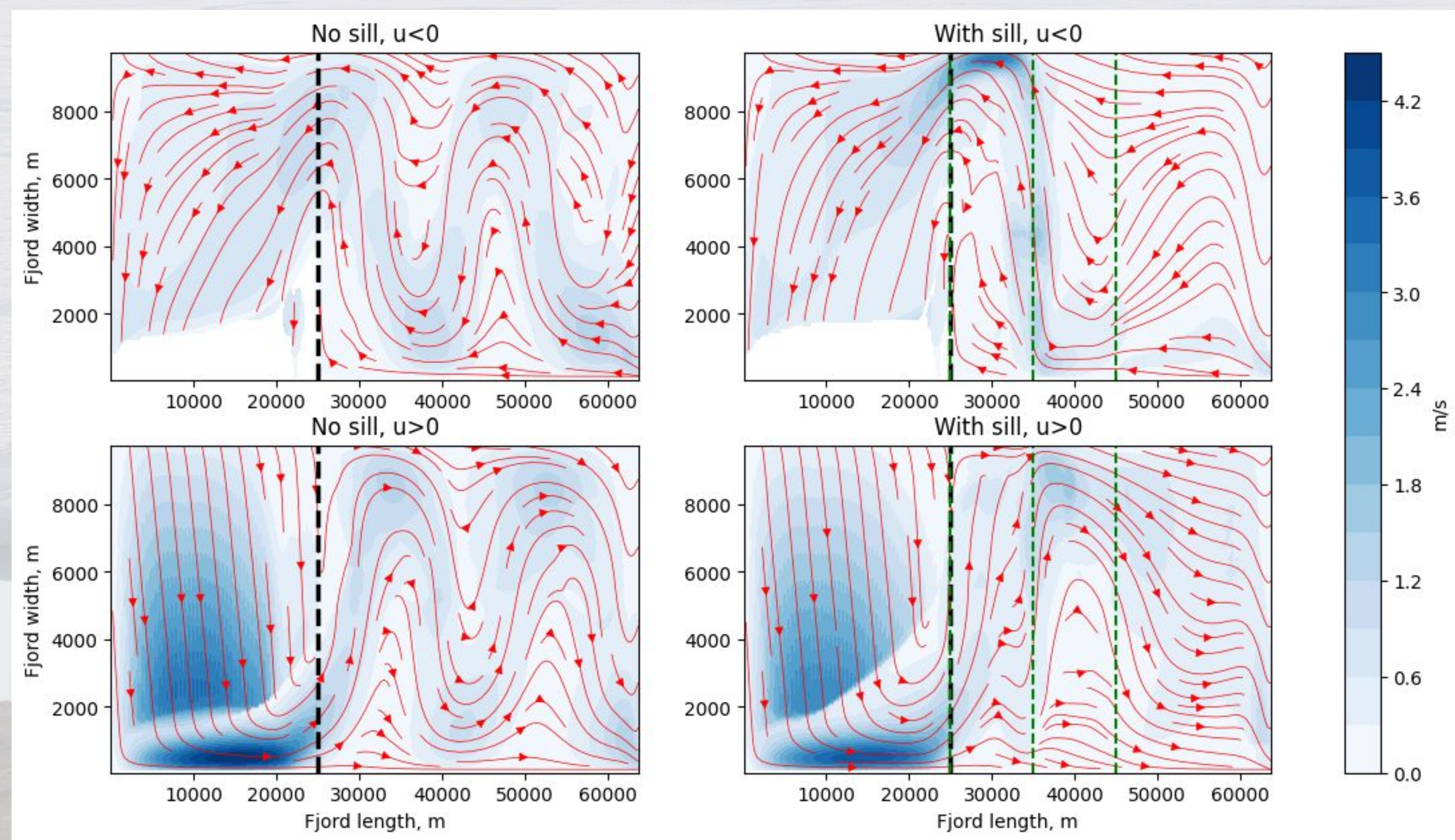
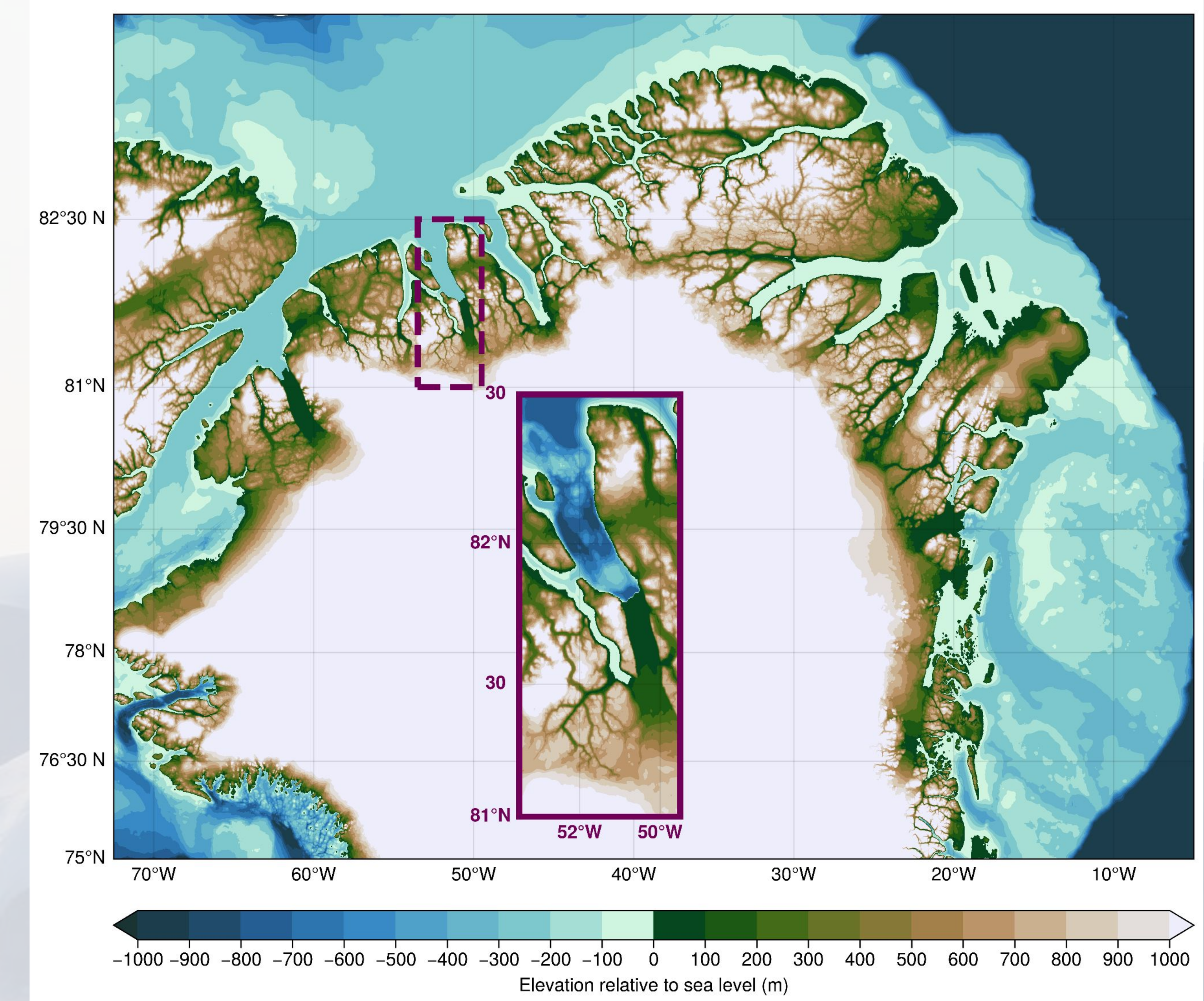


Figure 6: Horizontal velocities and stream lines separated for in- and out-flow (top and bottom respectively) for simulations without and with a sill (left and right respectively). Colors show the aboslut horizontal speed.

Circulation

- Under the ice, the flow is concentrated on the rhs (w.r.t the flow direction)
- Inflow at depth, outflow at the ice ocean interface
- Outside the cavity eddies form with a width of around 10 km (5x local Rossby radius of deformation)



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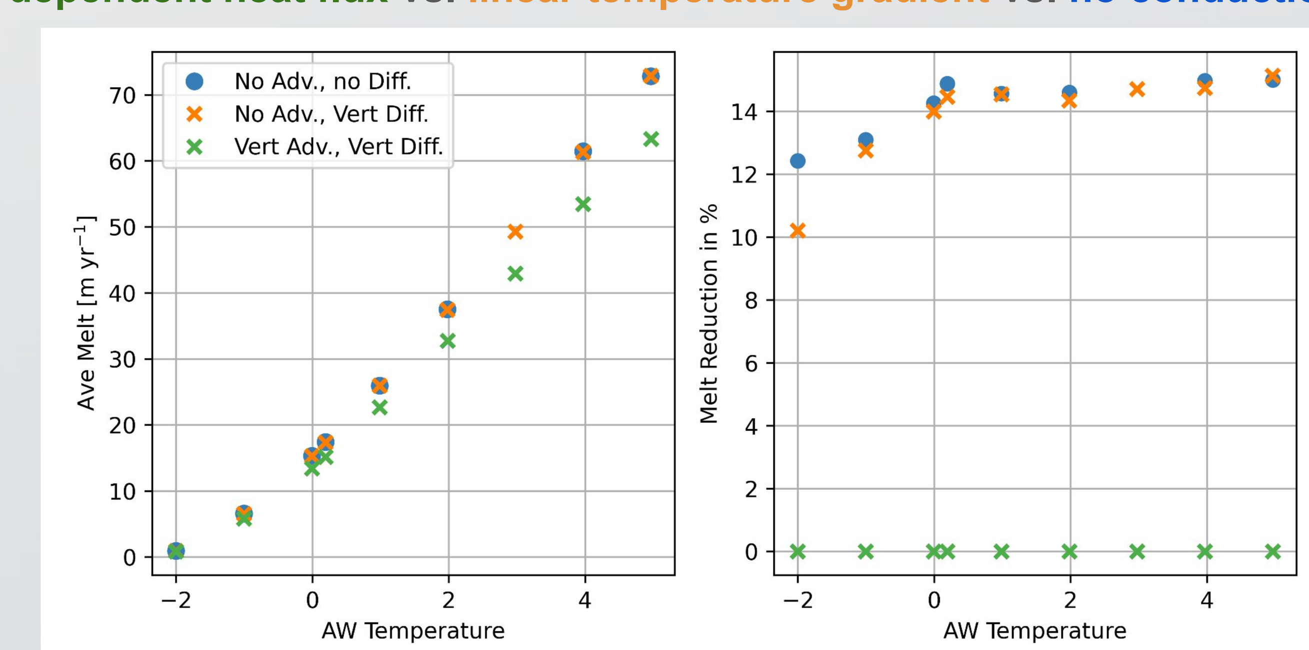

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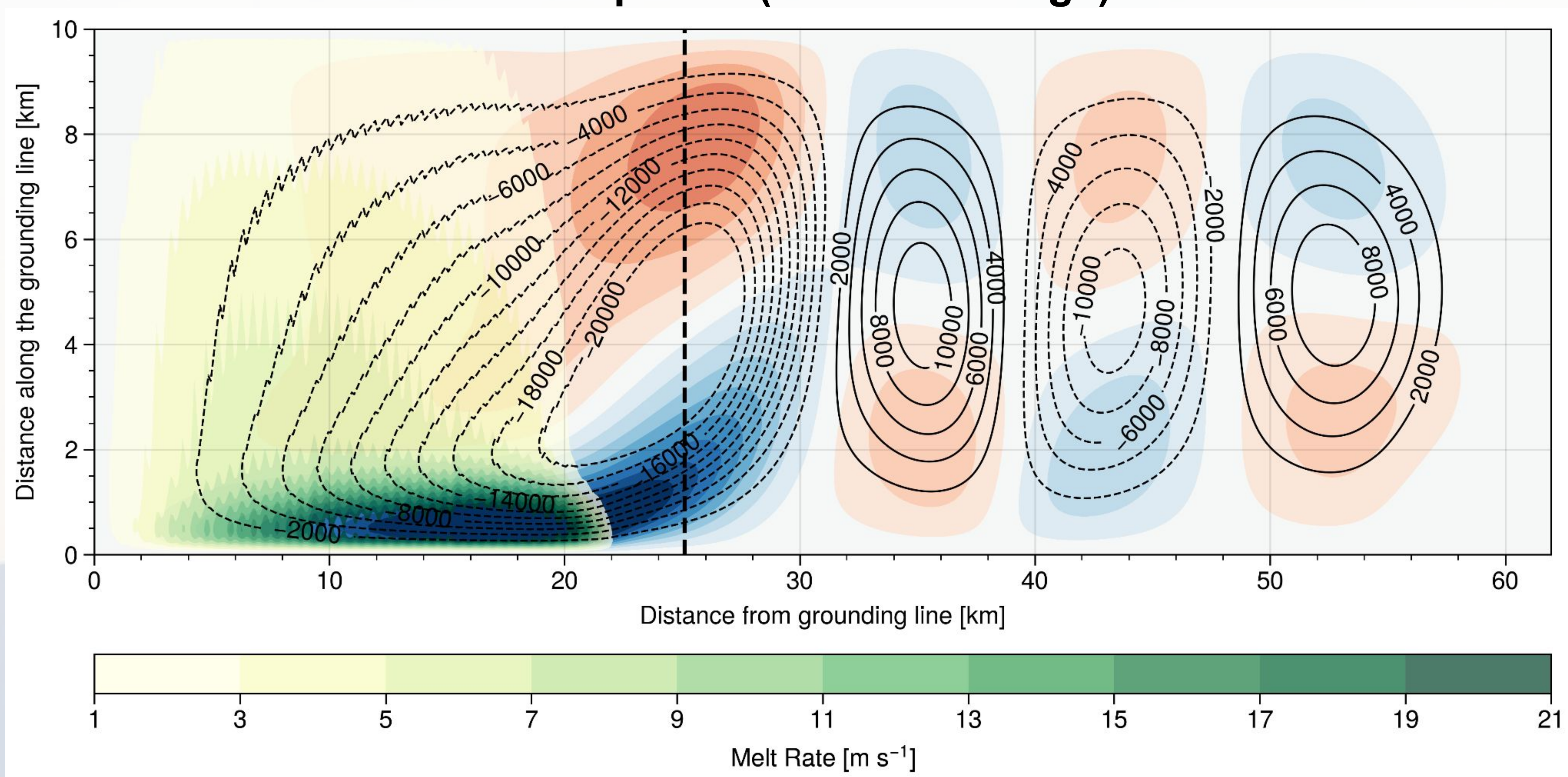

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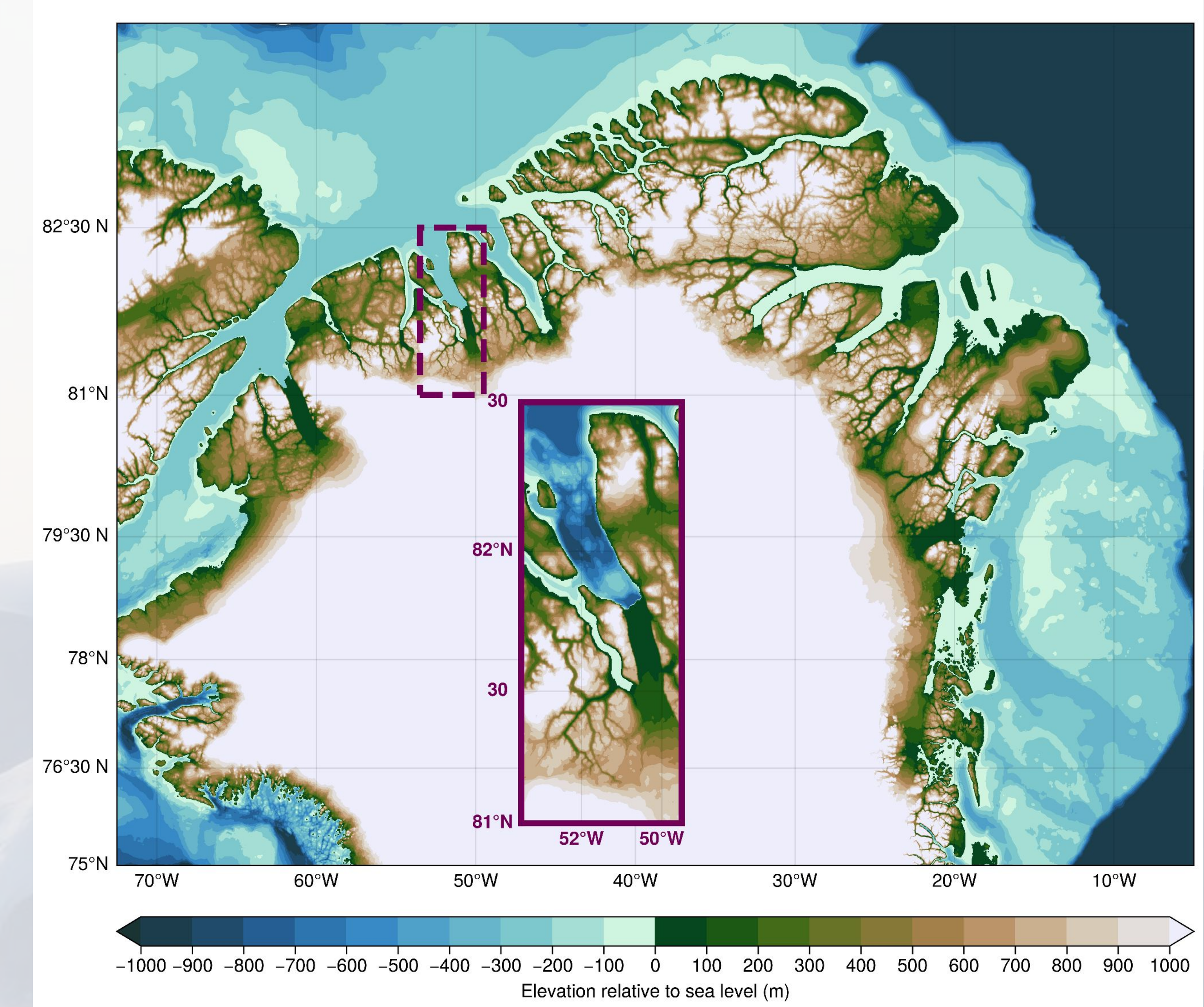

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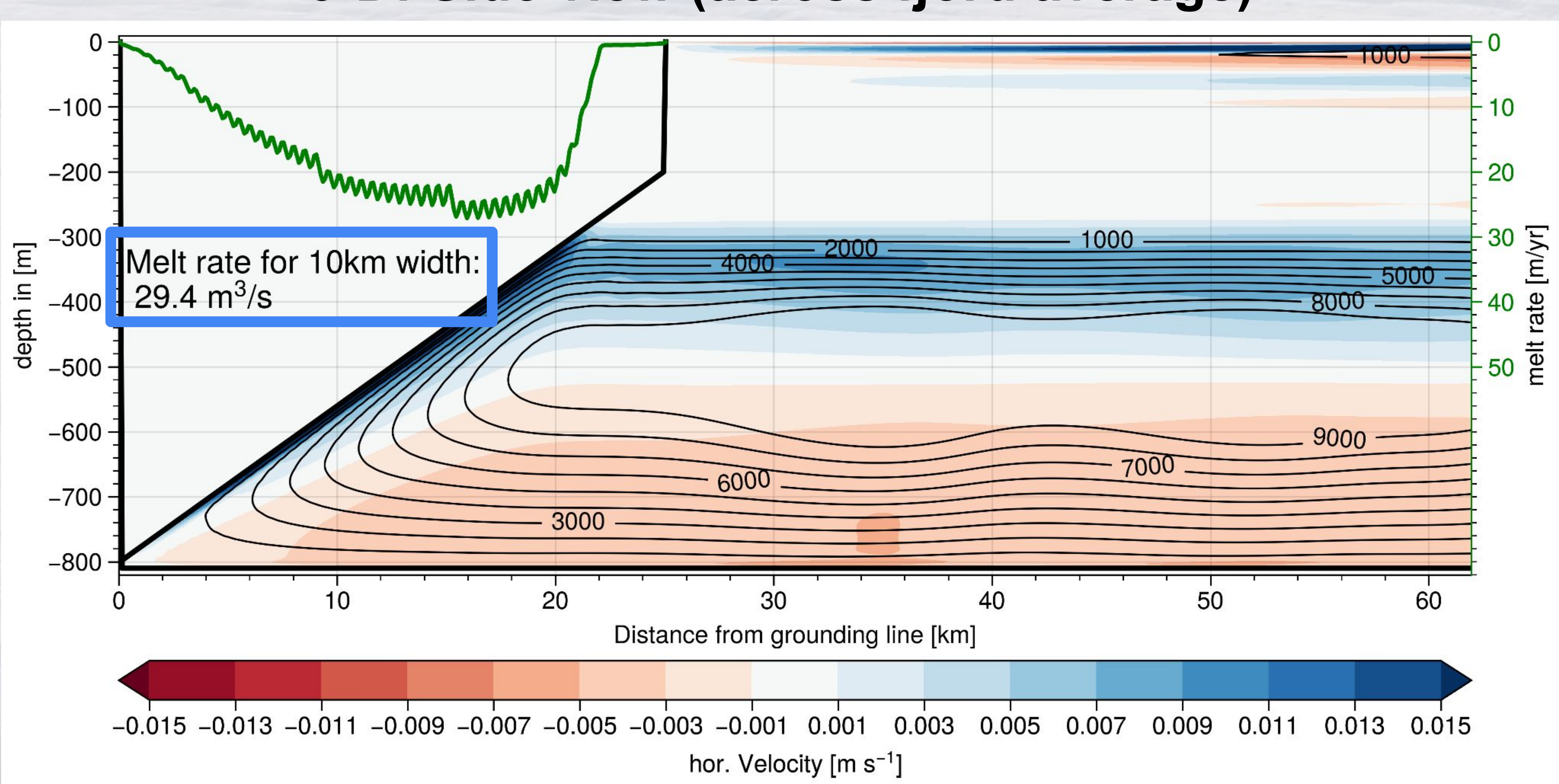

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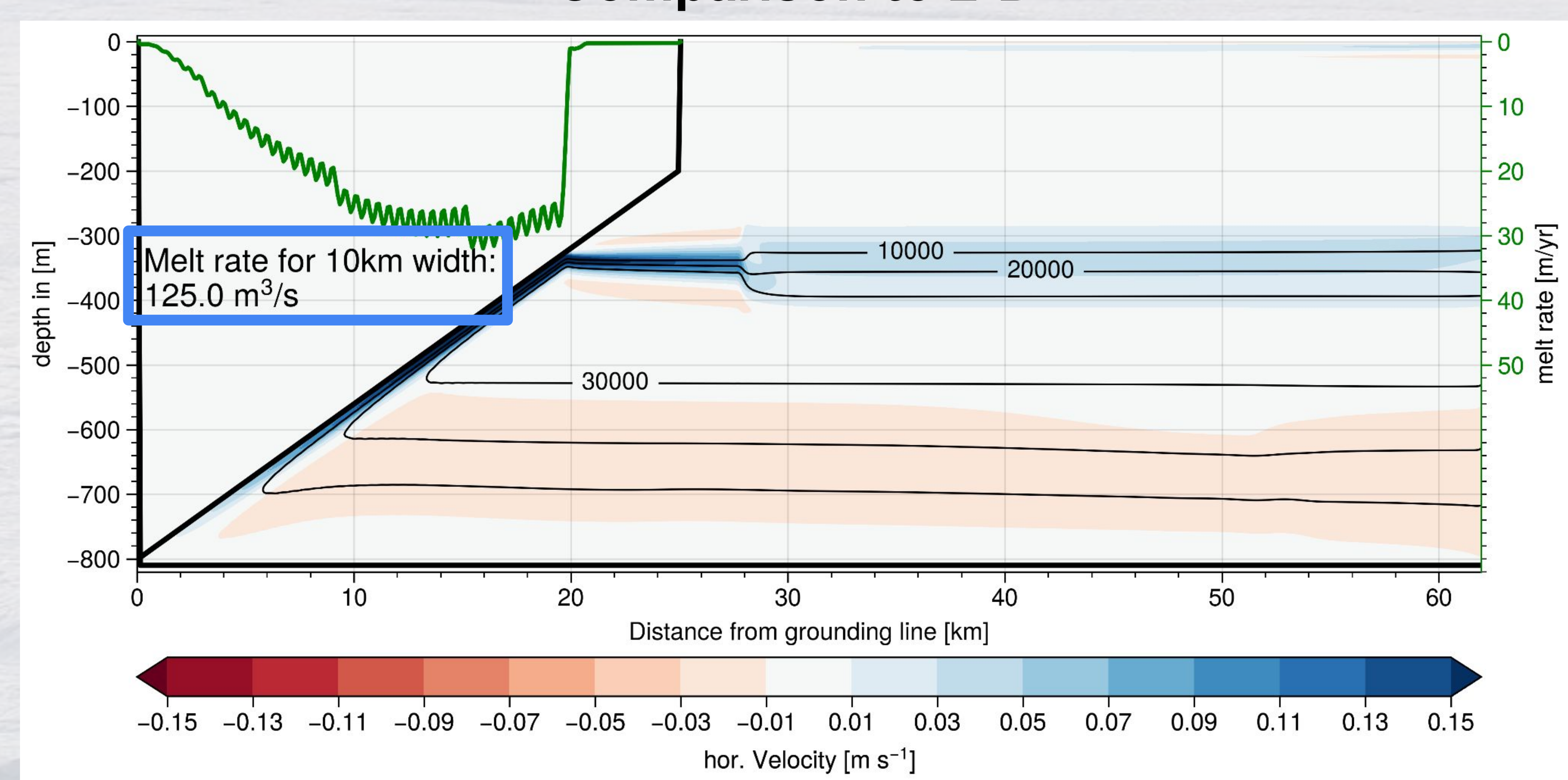
Comparison to 2-D



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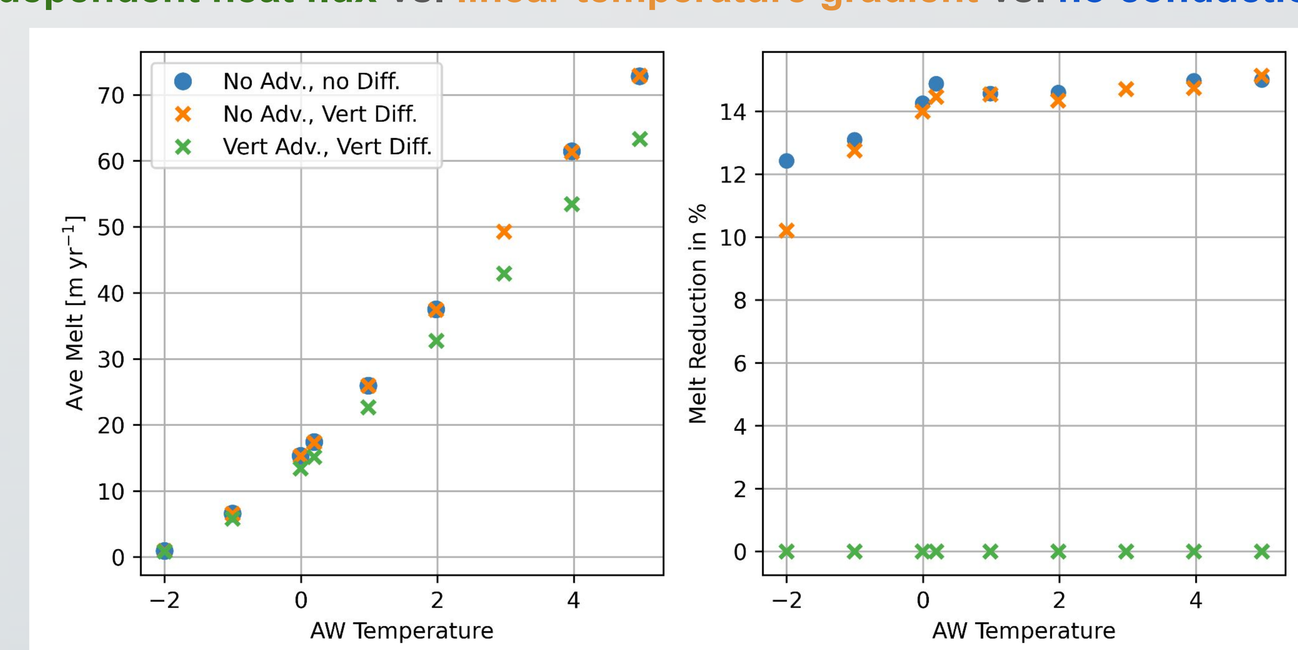

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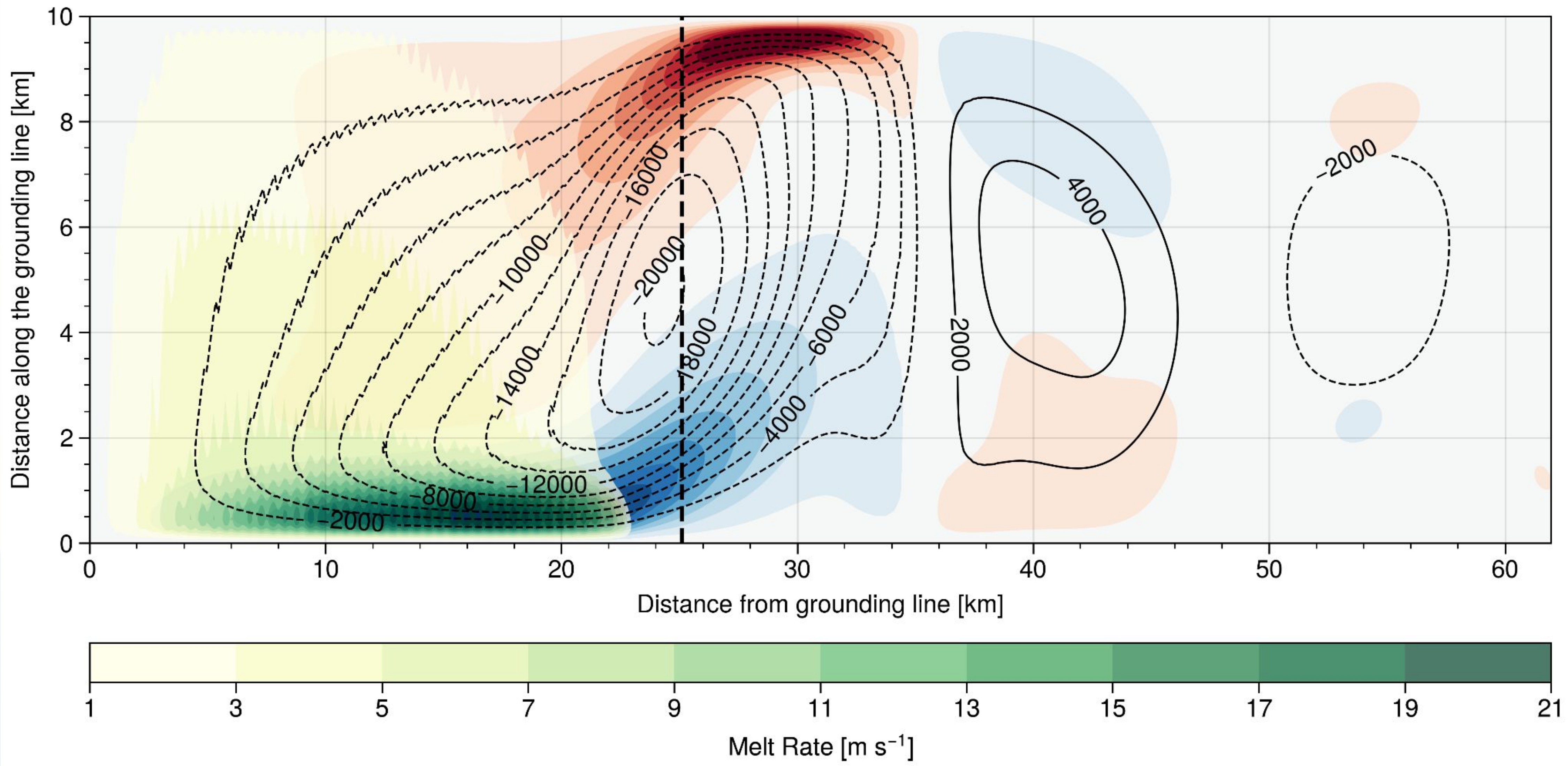

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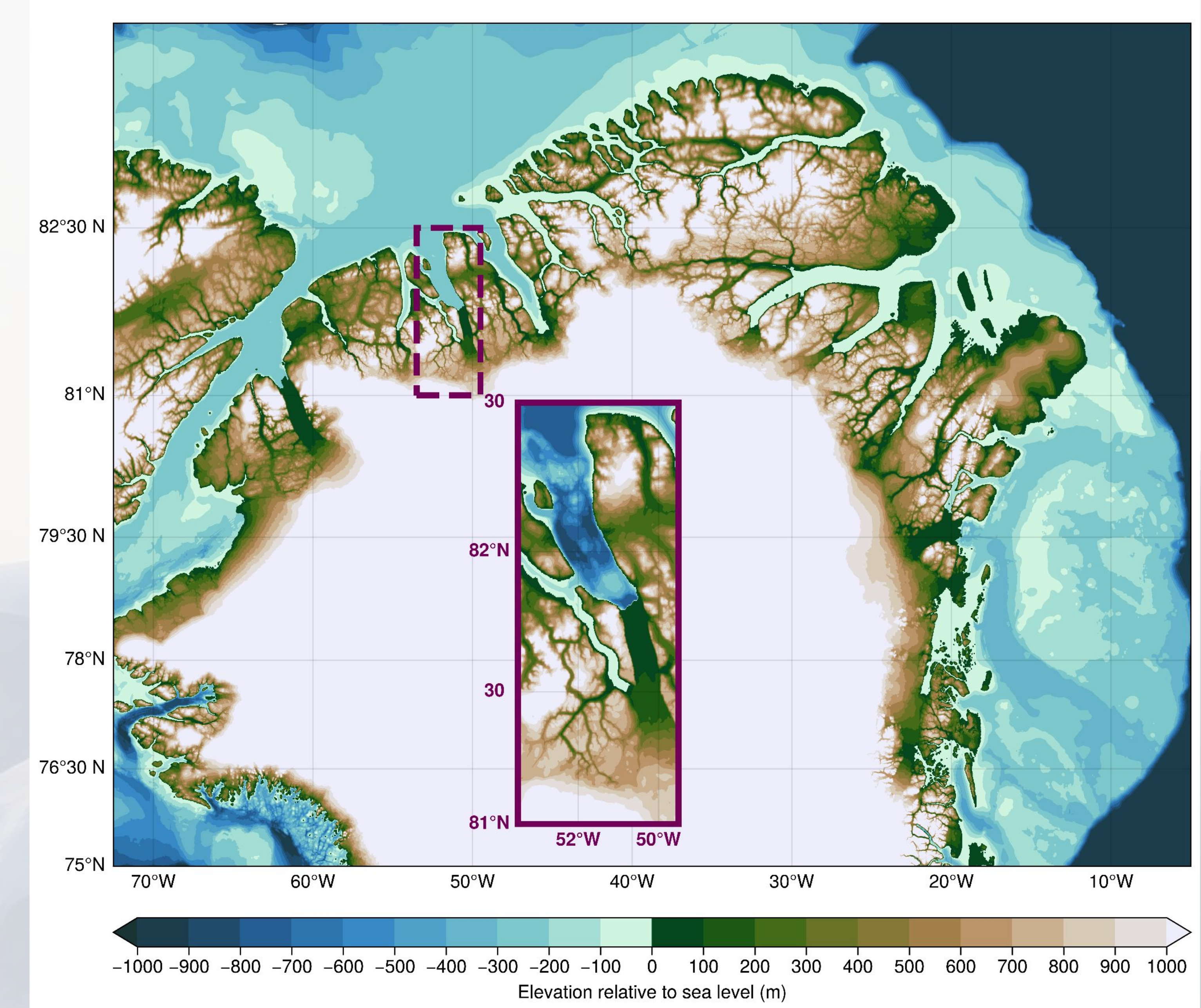

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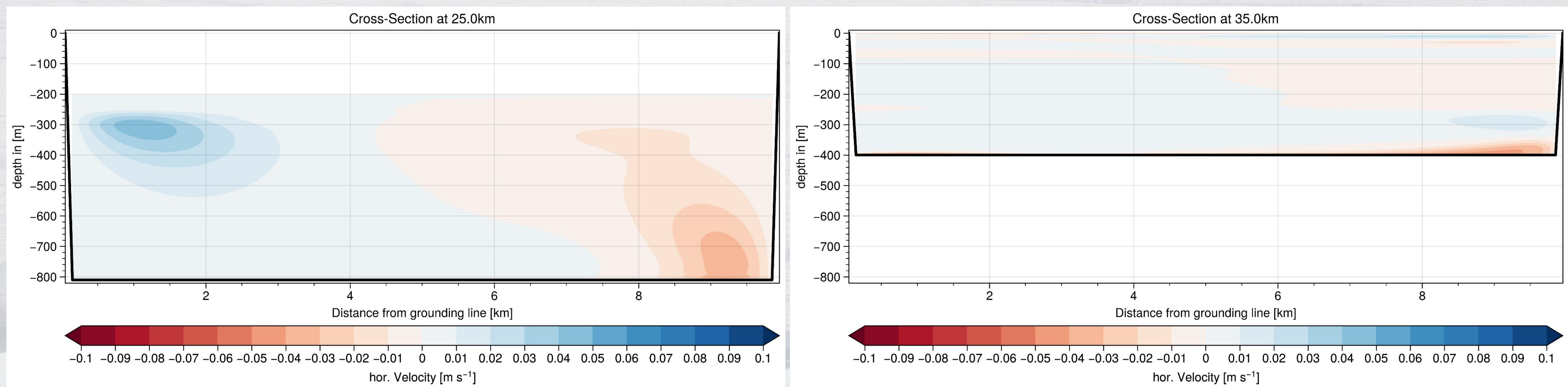
3-D: Cross-Sections - sill



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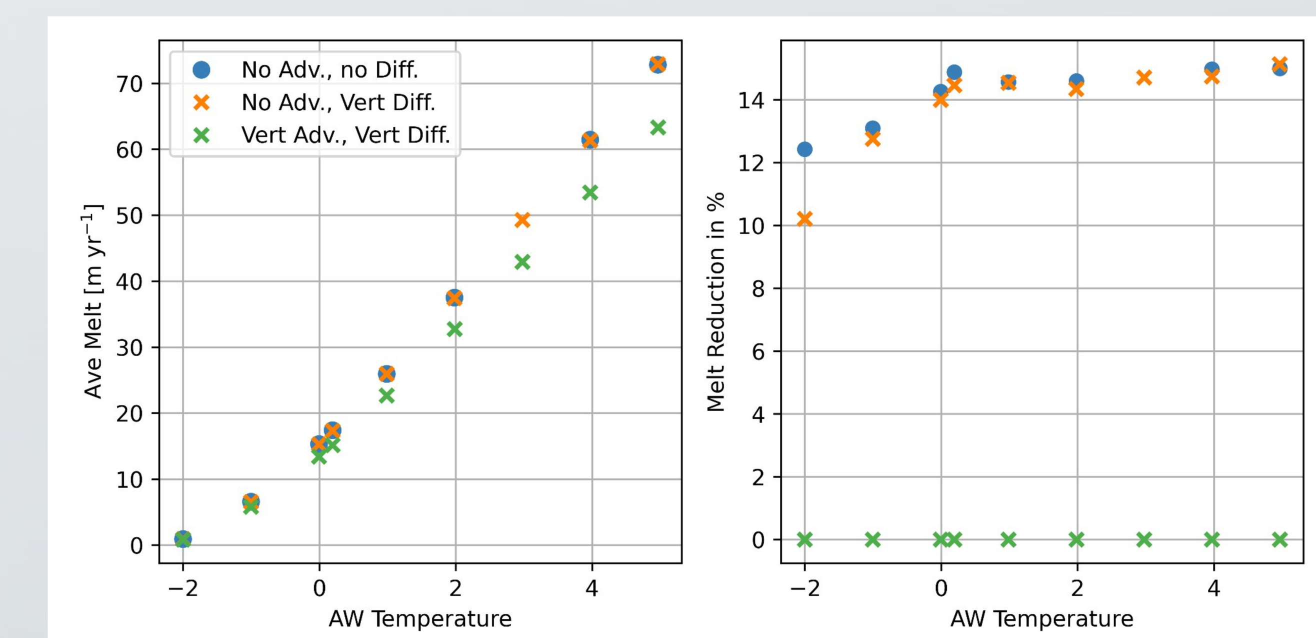

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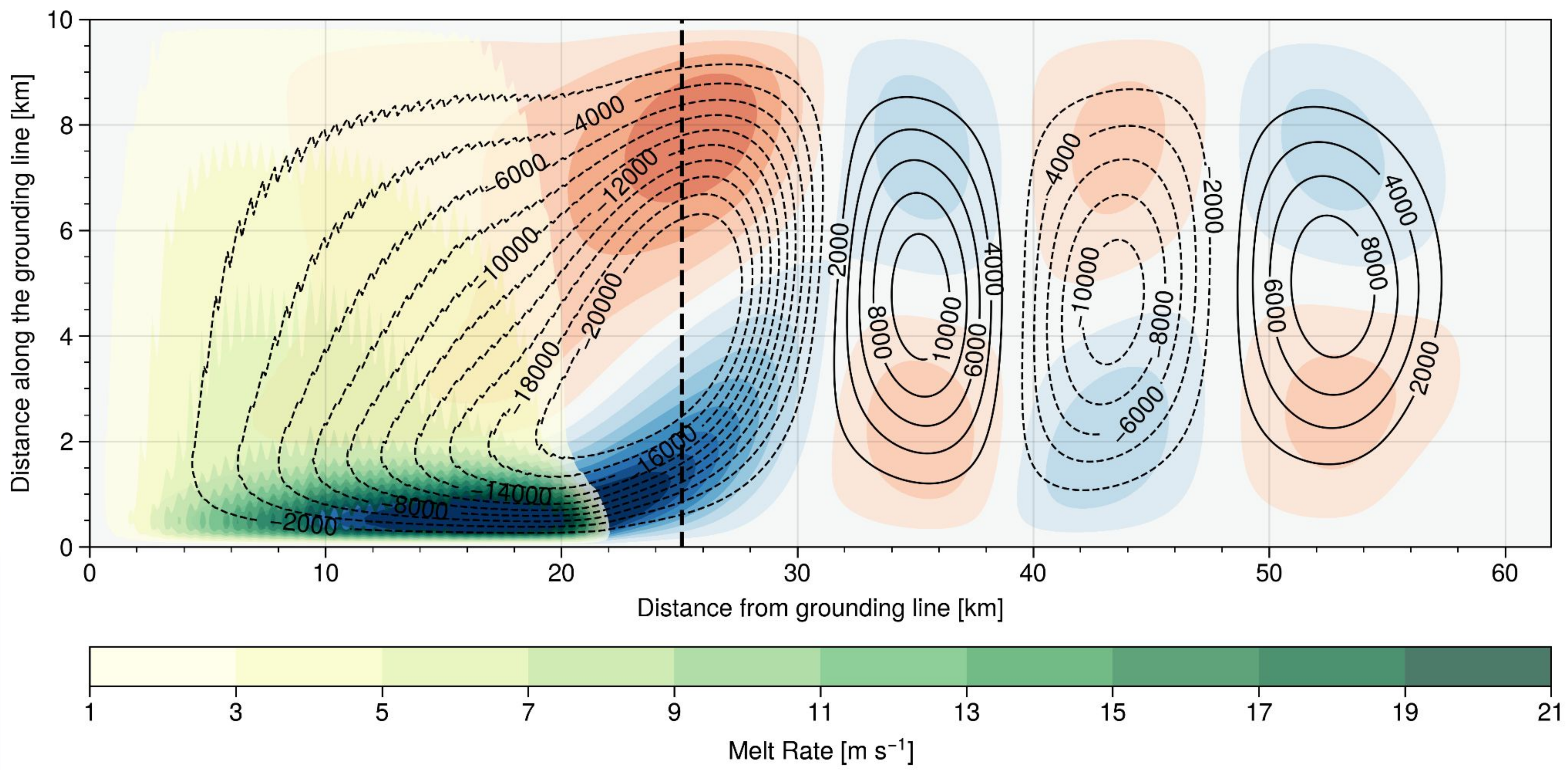

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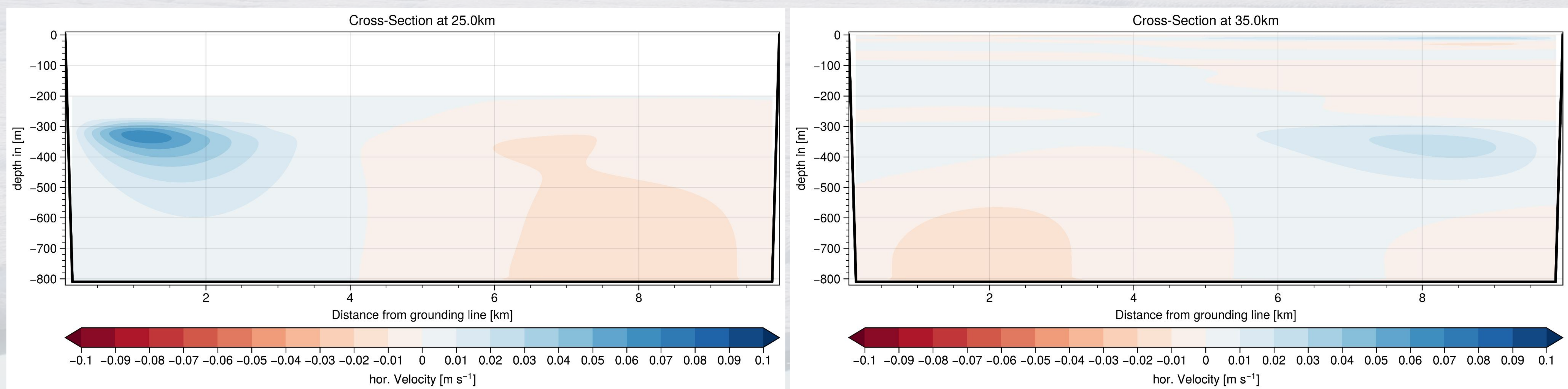

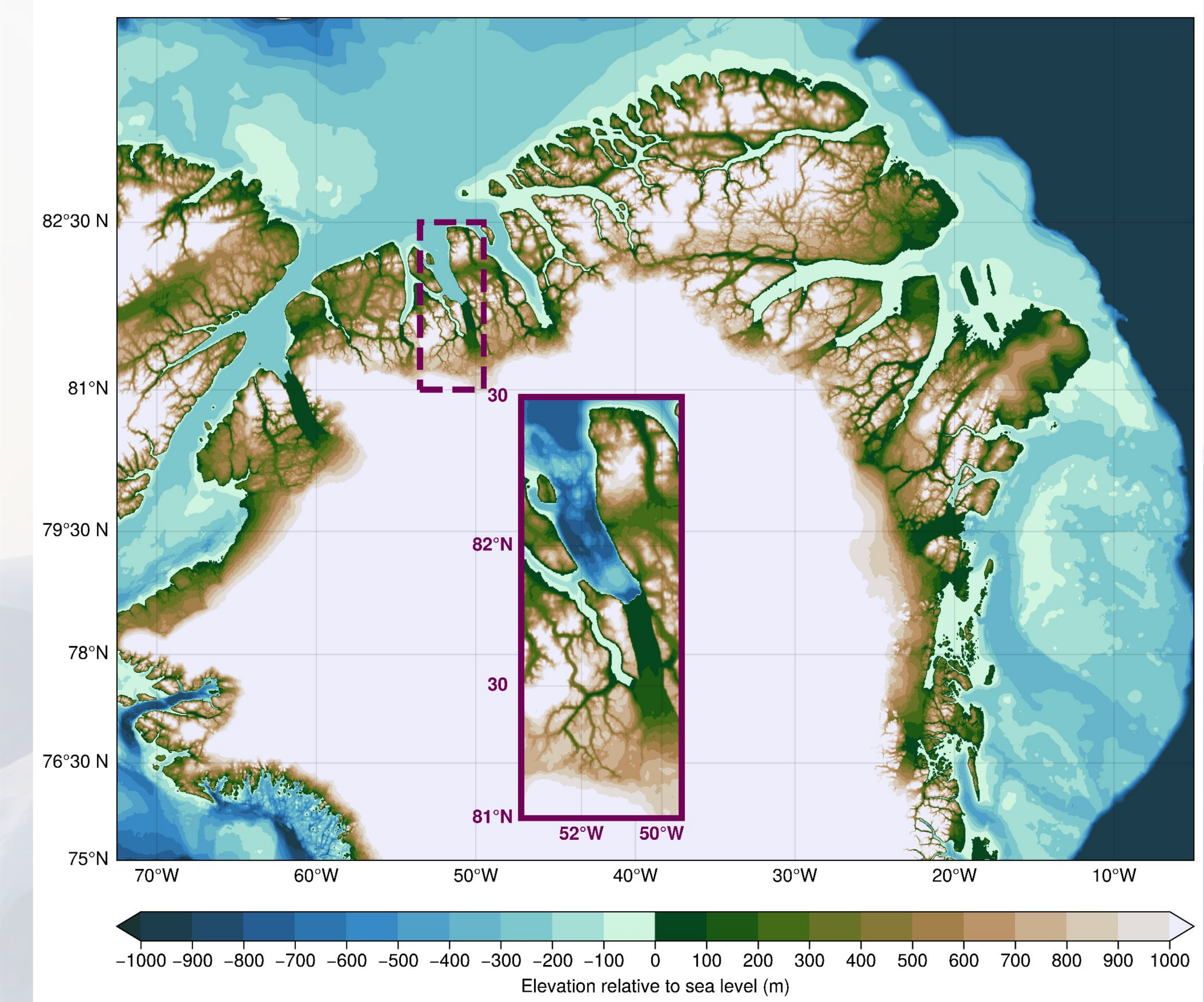

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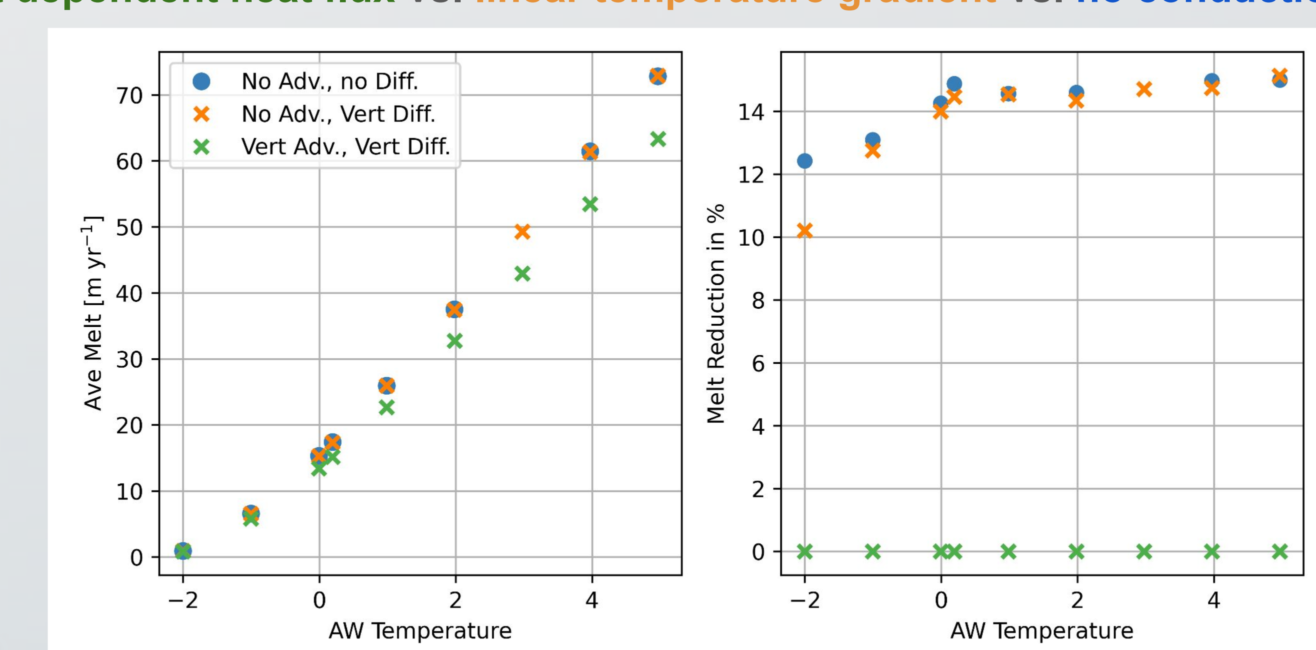

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