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How does the oceanic heat supply to ice shelves respond to yearly changes in the Amundsen icescape?

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Introduction & Methods

The heat transfer between the warm oceanic water and the floating portion of the Antarctic ice sheet (the ice shelves) occurs in a dynamic environment with year-to-year changes in the spatial distribution of ice shelves, icebergs, and fast-ice (the **'icescape'**). Dramatic events such as the collapse of glacier tongues are apparent in satellite images but oceanographic observations are insufficient to capture the synoptic impact of such events on the supply of oceanic heat to ice shelves. This study uses a 3D numerical model and semi-idealized experiments to examine whether the current high melting rates of ice shelves in the Amundsen Sea could be mitigated by certain icescape configurations. Specifically, the experiments quantify the impacts on oceanic heat supply of presence/absence of the Thwaites Glacier Tongue (TGT) and of the fast-ice cover seaward of Pine Island Ice Shelf (PIS).

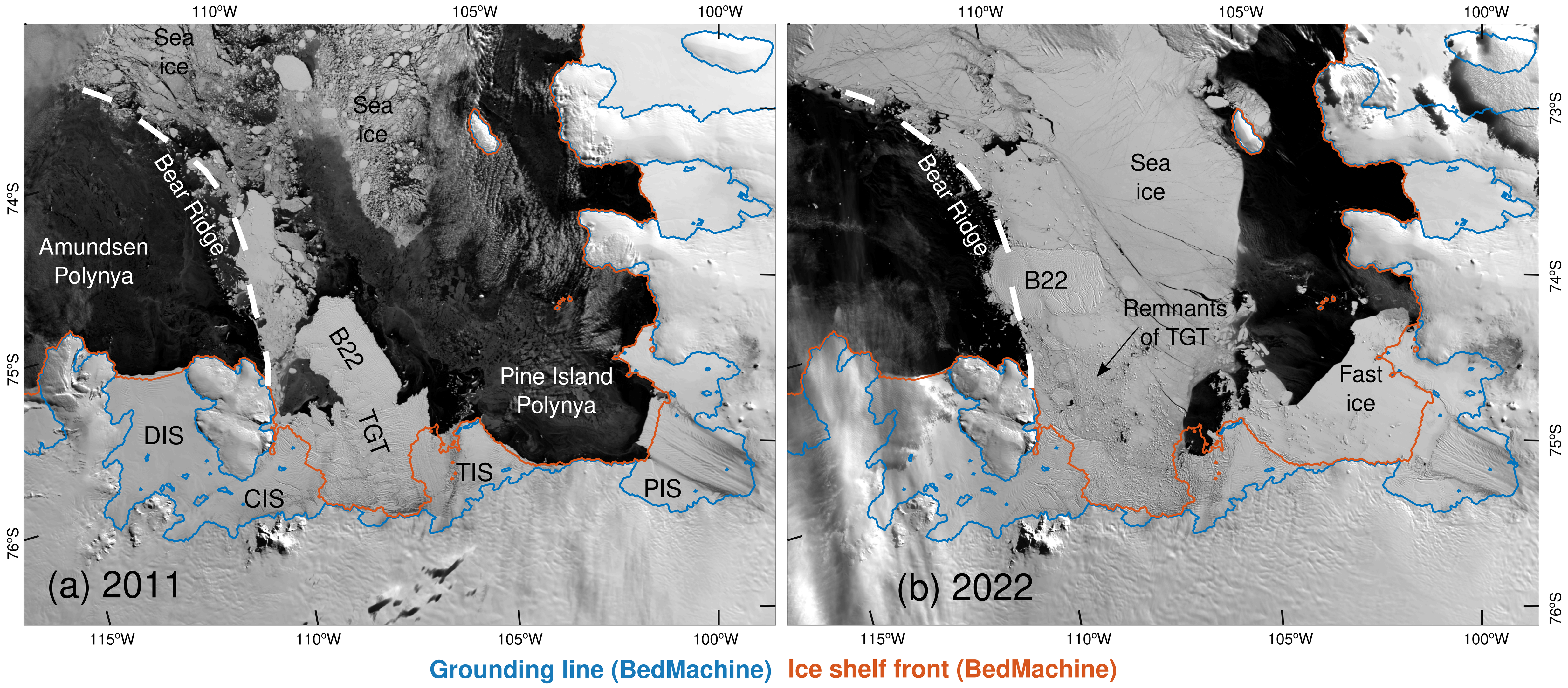

Figure 1: Contrast between two very different 'icescape' configurations in the eastern Amundsen Sea embayment. (**a**) Thwaites Glacier Tongue (TGT) at its maximum extent (*Scambos et al.*, 2022, 9 March **2011**). B22 is a tabular iceberg joined to the TGT on this date. (**b**) Complete breakup of the TGT into small individual icebergs, with a fast-ice cover between Thwaites Ice Shelf (TIS) and Pine Island Ice Shelf (PIS; 13 March **2022**). Icebergs and ice shelves are distinguished from sea ice or fast-ice by their corrugated appearance. The dashed line represents Bear Ridge. DIS: Dotson Ice Shelf, CIS: Crosson Ice Shelf. The grounding line and ice shelf front are from *Morlighem* (2020).

Results

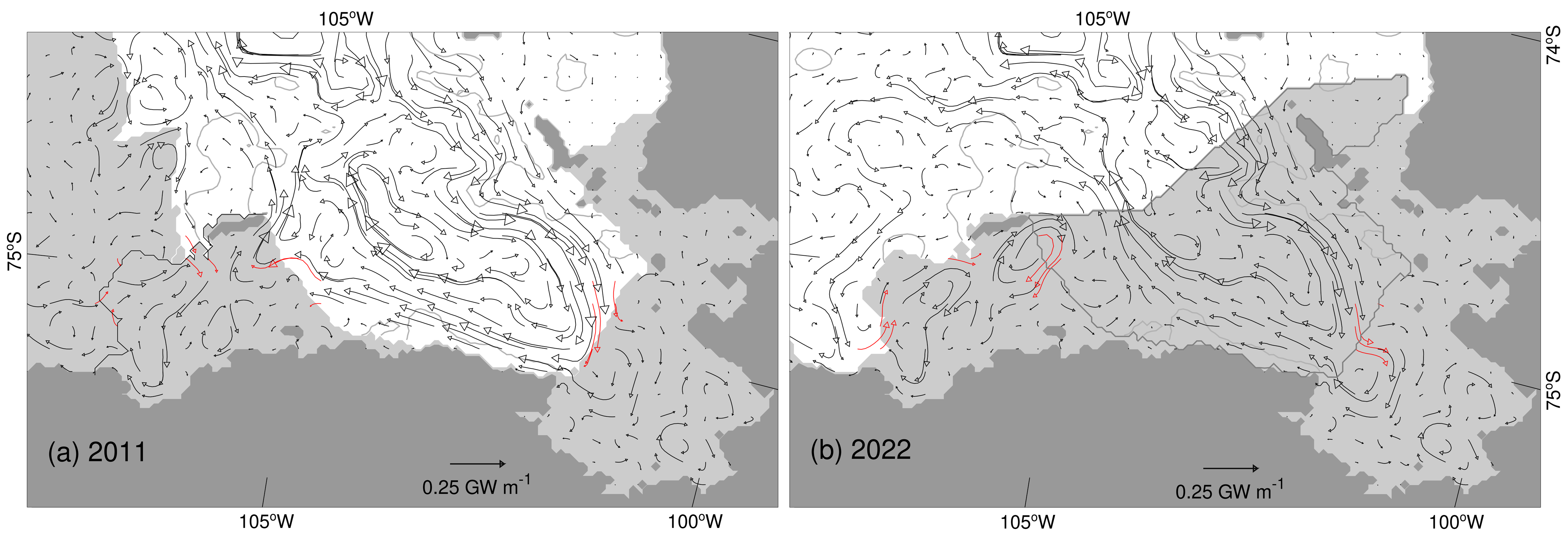

Figure 2: Horizontal oceanic heat flux in the vicinity of TIS,PIS in the (**a**) **2011** and (**b**) **2022** icescape configurations. The heat flux is vertically-integrated from the sea floor to the surface and averaged over the year. Only one vector out of five is shown for clarity (see Fig. 4 for a close-up of TIS). Locations of heat inflow are highlighted in red. *Note that: (1) the heat flow patterns are complex, (2) heat enters the ice shelves from multiple points, (3) the heat flow pattern around TIS changes dramatically between the two icescape configurations, and is more vigorous in the absence of a TGT, (4) the clockwise gyre seaward of PIS is substantially weaker in presence of the 2022 fast-ice cover.*

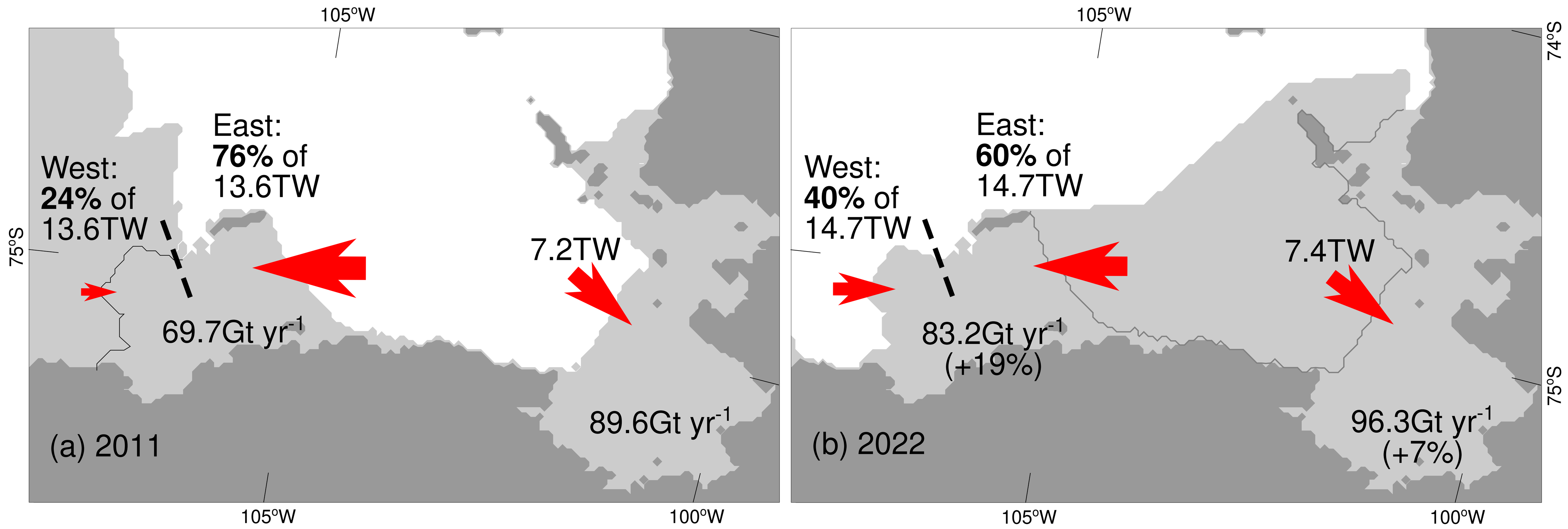

Figure 3: Horizontal heat flux entering TIS,PIS (red arrows) in the (**a**) **2011** and (**b**) **2022** icescape configurations. The value in TW is obtained by integrating all incoming fluxes across the vertical dimension and across the length of the ice shelf front. Ice shelves consume only a small fraction of the heat circulating through them (*e.g.*, *Jourdain et al.*, 2017) and thus this influx is balanced by a heat outflux (not shown) of the same order of magnitude. The difference (influx minus outflux) is what drives basal melting (in Gt yr^{-1} in the figure). For TIS, the heat influx is computed separately for the west/east portions of the ice shelf front (defined by the dashed black line). *Note that: (1) either side of the TIS front provides enough heat to fuel the melt of TIS (redundancy), (2) the disappearance of the TGT from 2011 to 2022 makes the western influx ≈ twice as important, (3) the overall heat influx to TIS and PIS (and their basal melt rate) remain very high in either icescape configuration.*

Discussion

The full study (*St-Laurent et al.*, submitted) extends this analysis to Dotson and Crosson ice shelves. The same key result is apparent, namely, that *ice shelves in the Amundsen embayment have multiple viable pathways for heat supply.* Major disruptions of their 'icescape' environment are simply countered with a re-distribution of the heat influx across those pathways so that their high melting rates are maintained. Although Fig. 2 highlights the complexity of those pathways and the expected challenges associated with their observation, recent fieldwork do support the existence of multiple heat inflows to the TIS (see Fig. 6 of *Wåhlin et al.* (2021), as well as *Girton et al.* (2019) in the case of Crosson Ice Shelf).

The 2011 and 2022 icescapes differ by the presence/absence of the TGT but also of a fast-ice cover seaward of PIS (Fig. 1). Although not shown in this poster, sensitivity experiments from the study indicate that both the TGT collapse and the presence of the fast-ice cover enhance the heat supply of TIS. The TGT collapse is associated with more heat from the west (Fig. 3), while the fast-ice cover is responsible for raising the thermocline by ∼ 100 m under TIS. The modeled thermocline closely follows *Dotto et al.* (2022)—the fast-ice cover spins down the Pine Island gyre and flattens the dome-shaped baroclinic field to raise temperatures under TIS.

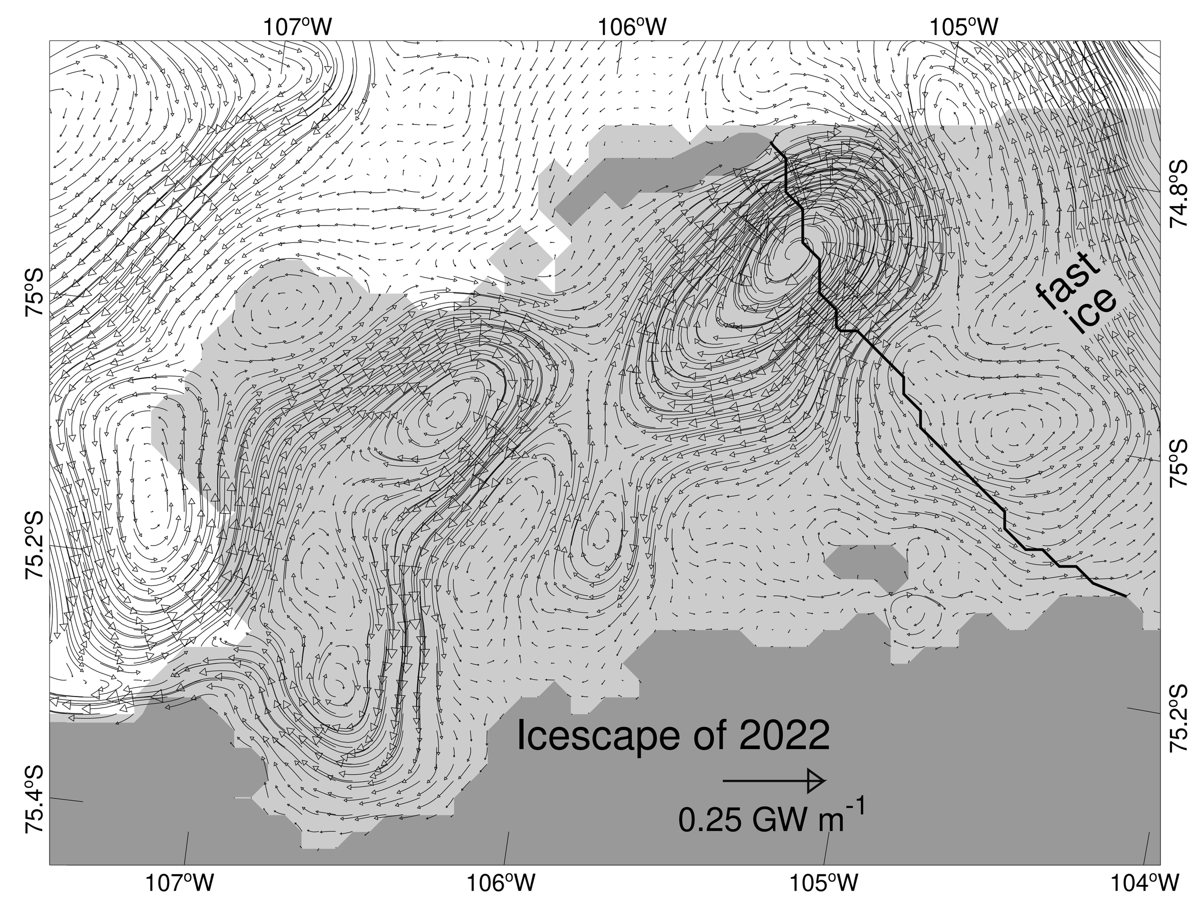

Figure 4: Same as Fig. 2b but showing every arrow in the TIS region.

Other components of the Amundsen cryosphere not discussed here are likely to play a role in the heat supply of ice shelves. *Bett et al.* (2020) examined whether iceberg melt along the Amundsen coast could mitigate basal melting rates. They obtained an increase in bottom water temperatures which they attributed to weaker wintertime cooling from the strengthened haline stratification. Sea ice production and melt also has the potential to modify the hydrography upstream of ice shelves (*Webber et al.*, 2017) and this topic is under investigation (*Stammerjohn et al.*, 2022).

Acknowledgments

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