National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

From the Seasonal to the Decadal: Inferring Ice-Shelf Submarine Melting Changes from ICESat-2 Observations to Assess their Relationship to Ocean Variability

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Strategic Focus Area: Ocean and ice

The overarching science goal is to investigate the crucial role of the interactions of Antarctic ice shelves with the ocean and consequent submarine melting in the stability and evolution of the ice sheet.

The science objectives that we proposed to implement to address the science goal are**:**

- Calculate ice-shelf basal melting rates at seasonal to annual timescales from altimetry measurements and ancillary data for ice shelves in the Amundsen and Bellingshausen seas of West Antarctica in the period 2010 to the present.
- Apply the adjoint mode of the Massachusetts Institute of Technology General Ocean Circulation Model (MITgcm), additionally constrained with submarine melting patterns inferred from observations, to simulate oceanographic variability on seasonal to annual time scales on the continental shelf during the study period.
- Determine if improved observational understanding of extrema in the sub-annual variability of ice-shelf submarine melting has decadal-scale consequences for ice-sheet model projections of sea-level contribution from Antarctica.

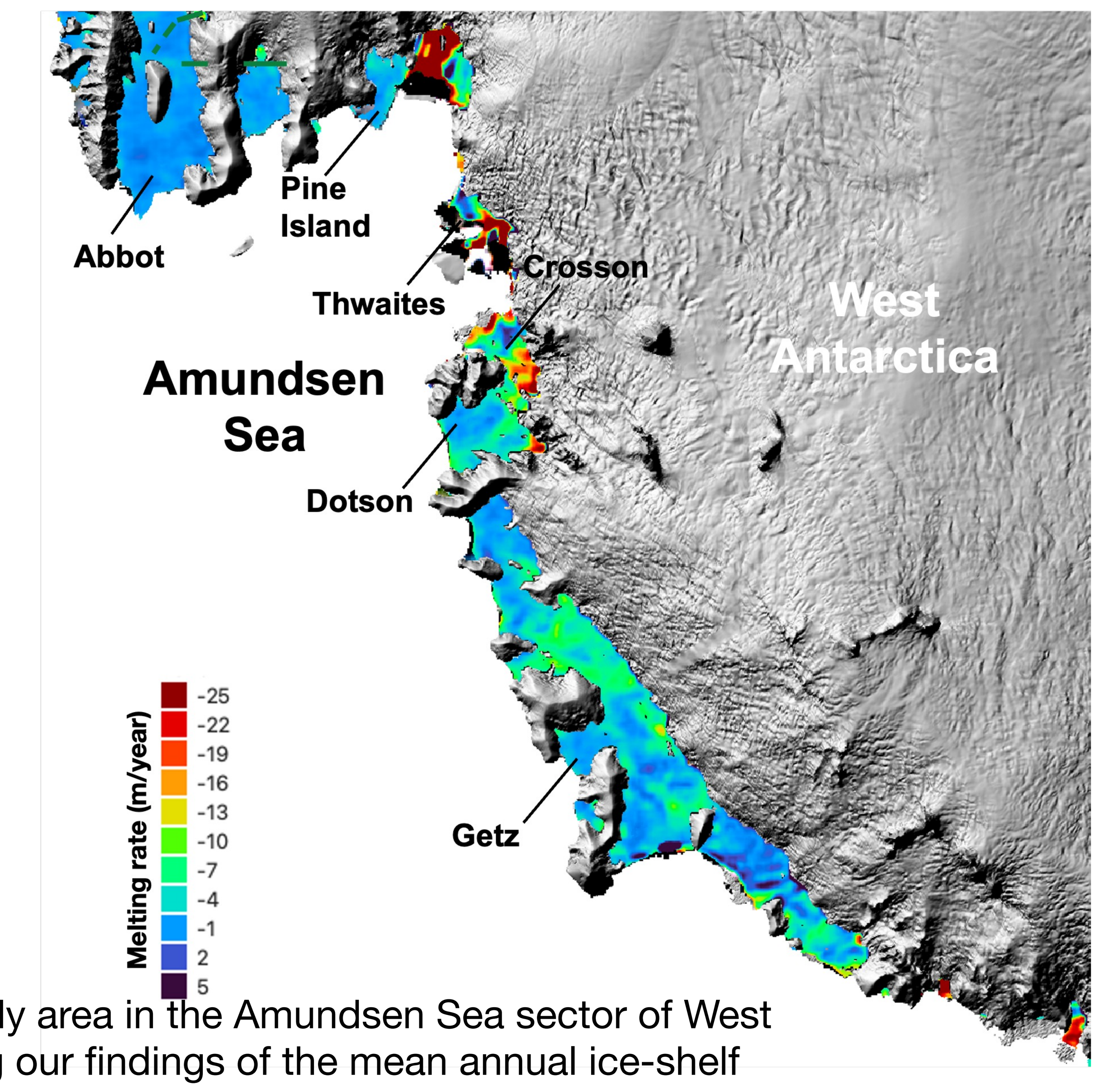

Figure 1. The study area in the Amundsen Sea sector of West Antarctica showing our findings of the mean annual ice-shelf submarine melting rates in the period 2010–2021. Reddish colors indicate higher melting.

Results:

Altimetry and Melting Rates from Observation:

Several iterations of the processing chain were performed to improve inferred basal melting rates quality. This included improvements in software to generate the DEM and the elevation time series to reduce noise and provide 1-km resolution, reducing noise and producing smooth estimates of the needed gradients to allow for annual to sub-annual estimates of melting rates. Examples of the results are shown in Fig. 1 and Fig. 2.

Ice Modeling:

Estimates of FAC and SMB and their uncertainties have been made from 1992 through 2022 in support of submarine melting rate calculations from altimetry.

Ocean-modeling optimization:

We applied the methods above to model runs for the period of 2019 and 2020, making use of the availability of ICESat-2 data, which was instrumental in estimating the observation-based melt rates. Figure 3 compares the melt rate from the observation-based estimate (a), the model using the original, spatially-invariant γ_T (b), and the model using the revised γ_T (c), in the vicinity of Pine Island Glacier. The maps clearly demonstrate that the revision of γ_T reduces the differences in melt rates between the observation-based estimate (Figure 4a) and the model using the spatially-invariant γ_T (Figure 4b). The updated model melt rate (Figure 4c) more closely resembles the observation than does the original model's estimate.

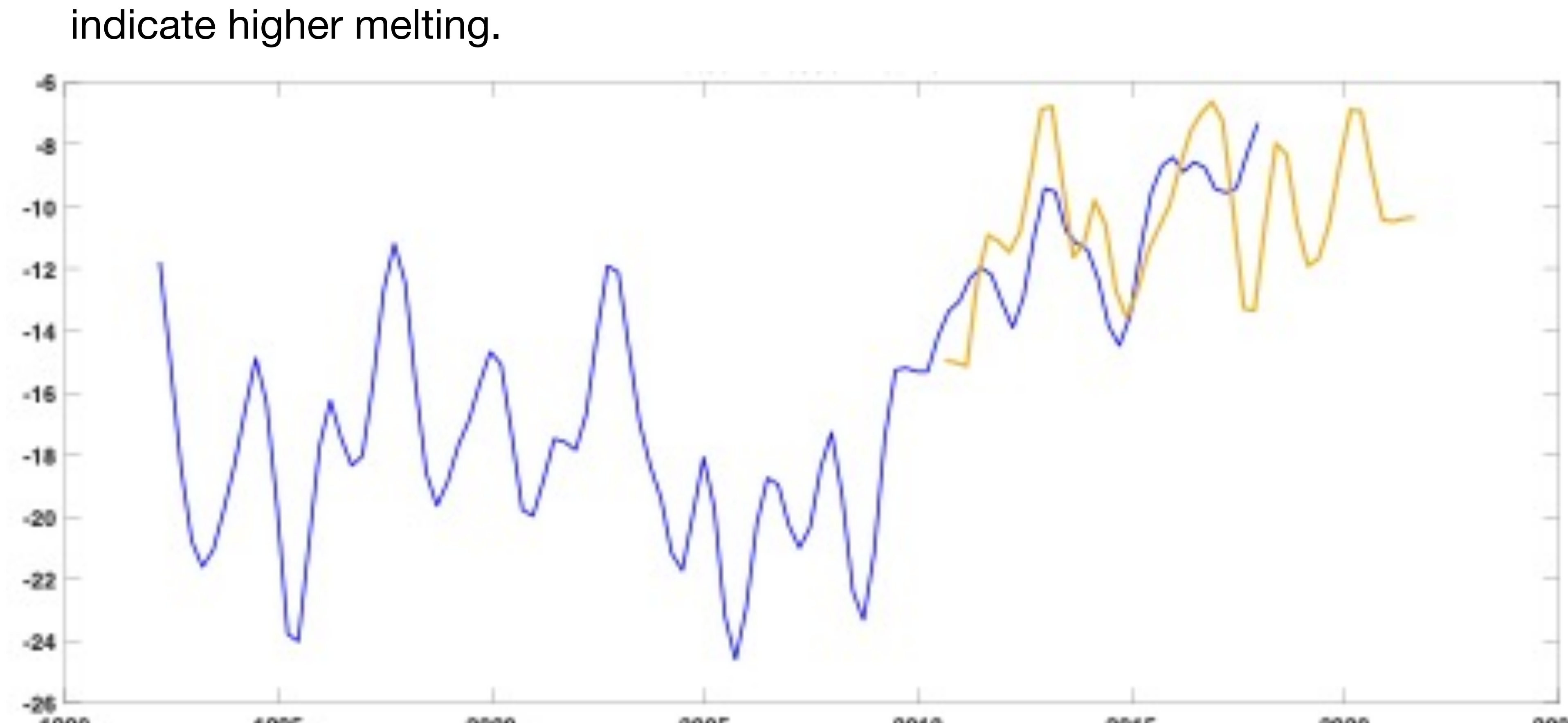

Figure 2. Times series of the high-melting rate areas (meters/year) near the grounding lines of the Dotson and Crosson ice shelves (indicated in Fig. 1). Blue is the time series from Paolo et al. (2023), while orange is the time series produced here. Our calculated melting rates align well with the previous and extend the time series to 2022, showing that in the case of these two ice shelves higher melting rates persisted.

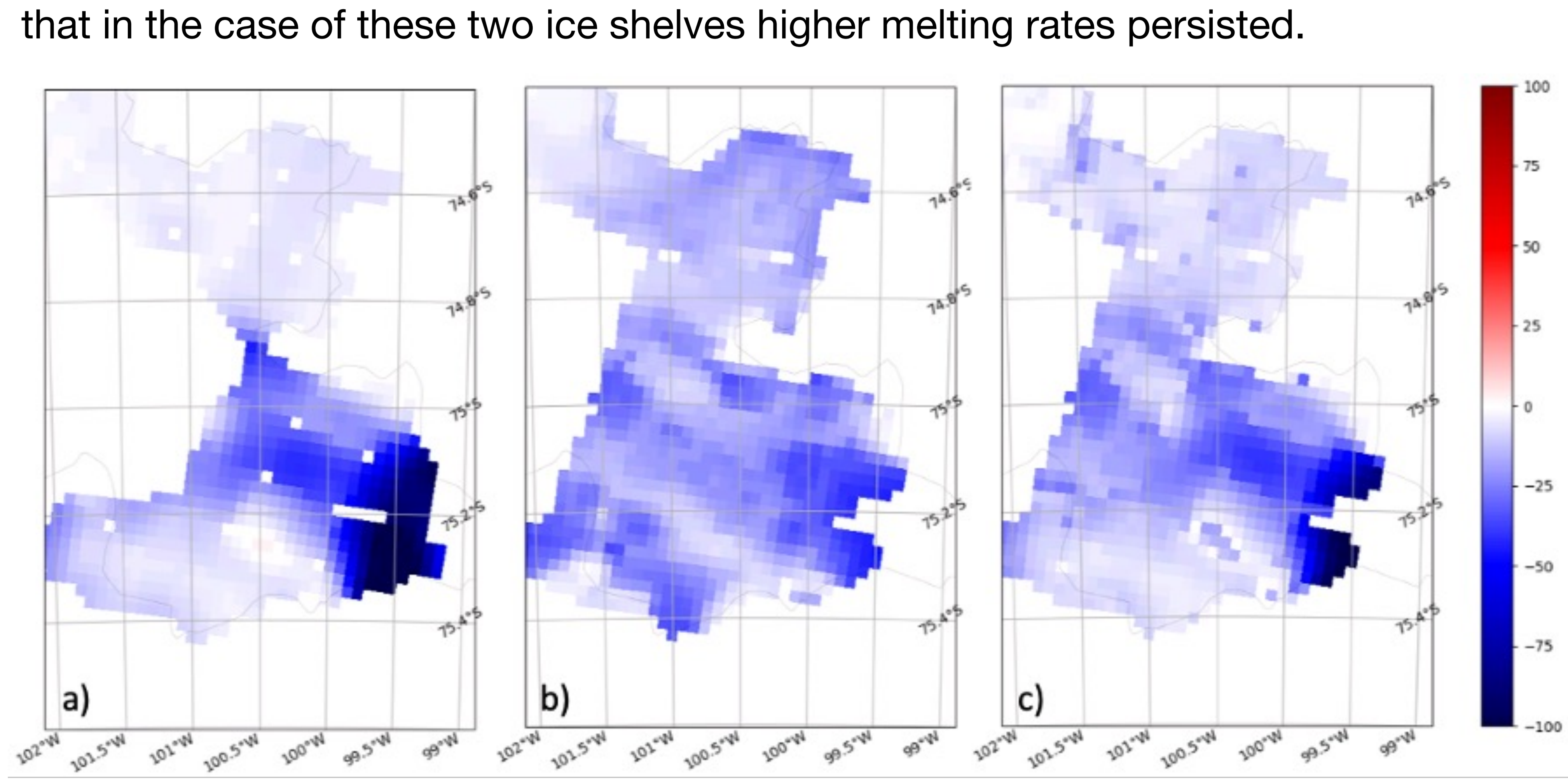

Figure 3: Melt rate estimates (m yr^{-1}) from observation (a) and models using original (b) and revised γ_T (c) around Pine Island Glacier.

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