National Aeronautics and Space Administration

Greenland Contribution to Sea Level by 2050: The Role of Meltwater in Shaping the Future Ice Sheet Evolution

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Earth 2050 - Strategic Initiative Leader: Joao P Teixeira

Objectives:

Within the ***Earth 2050 initiative***:

We aim to improve scientific understanding of the dynamic response of the Greenland Ice Sheet to climate change.

We leverage:

- **Observations**: to create a synthesized dataset of historical changes in ice fronts, velocities, and ice elevation.
- **Modeling**: to use observations to improve representation of surface melt and ice-flow-dynamic response.
- **Uncertainty Quantification (UQ)**: to develop innovative techniques and incorporate them into a projection ensemble framework.

Significance:

Earth 2050 aims to improve the understanding of fundamental climate science questions.

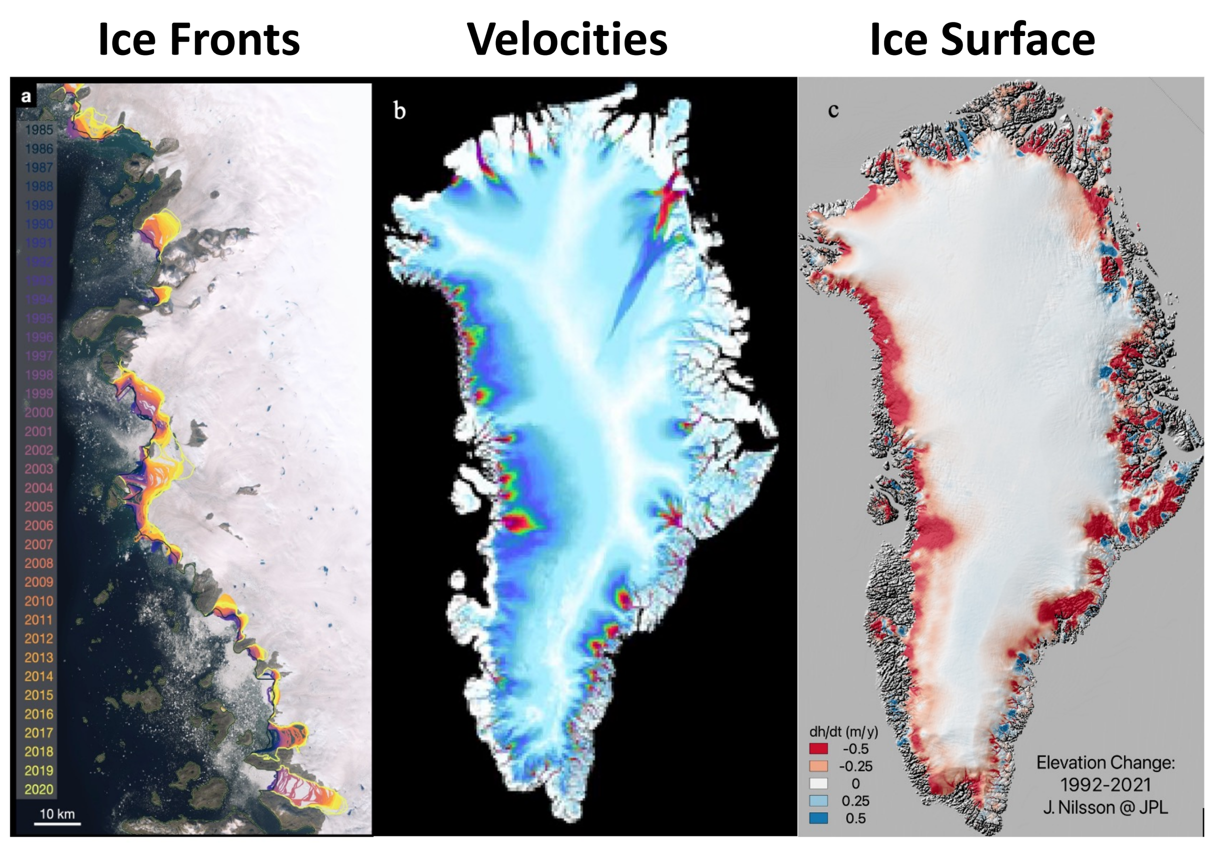
We address the stability of the Greenland Ice Sheet and its sea-level contribution 2050.

This framework improves model representation of Greenland ice dynamics by informing models with observations; assessing simulation error; and increasing certainty in future sea-level projections.

This effort:

- **consolidates the link between JPL observations and models.**
- **supports collaboration between JPL and Caltech.**

Background:



By 2050, Greenland surface melt, ice front-ocean melt, and ice flow are expected to accelerate. Yet, ice sheet models crudely represent the physical processes linking melt to glacier flow.

Here, we leverage 35 years of satellite observations to:

- ***characterize relevant melt-related processes***
- ***validate model simulation of ice dynamics***
- ***produce calibrated 30-year projections of Greenland***
- ***provide probabilistic uncertainties future scenarios***

The new framework will reveal what types of observations are needed to improve understanding and model representation of Greenland's response to climate change, and aid in the derivation of future mission requirements.

Approach and Results:

Observational datasets - compiled from various airborne sources - inform ice flow simulations using the **Ice-sheet and Sea-level System Model (ISSM)** and its **Glacier Energy and Mass Balance (GEMB)** module. Key features:

- **Improved initialization techniques** to infer basal conditions using temporal assimilation (Figure 1).
- **Improved modeling** of snow melt to produce climate forcing for dynamic ice flow projections (Figure 2).
- **Novel UQ** techniques provide uncertainties associated with inference of basal conditions (Figures 3 and 4).

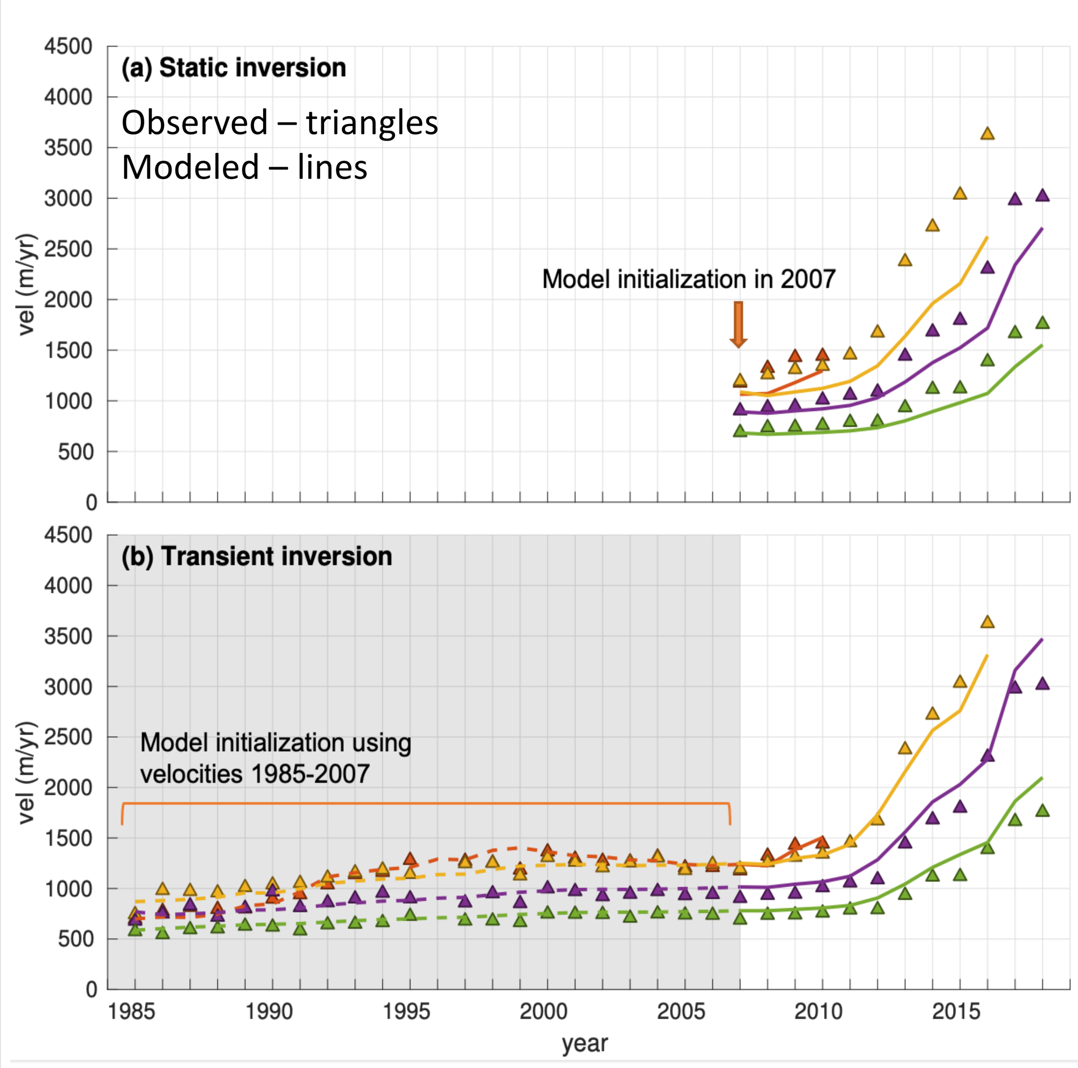
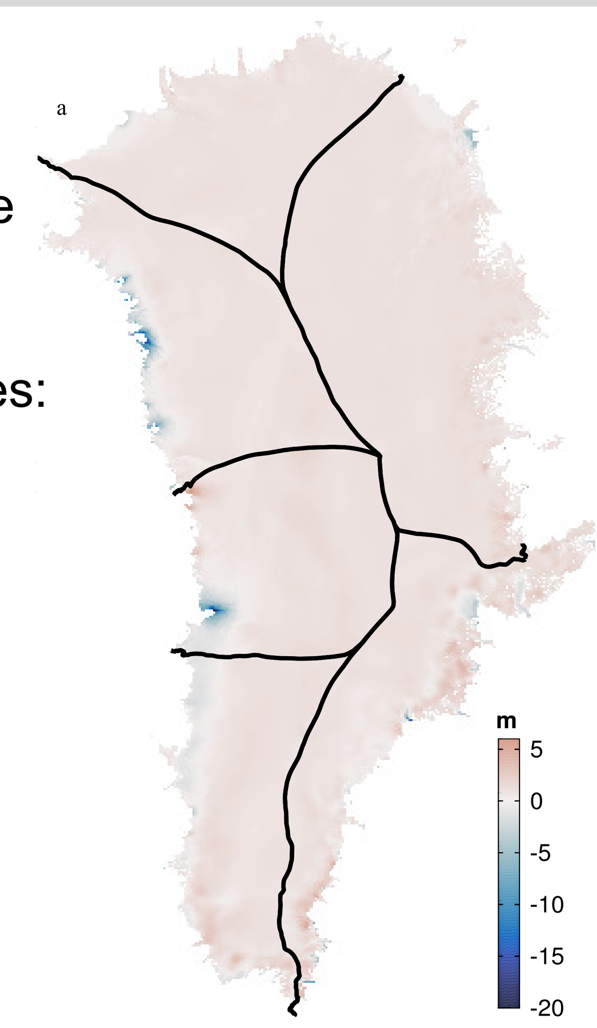


Figure 1: Improved Ice velocity simulation across Kjer Glacier, NW Greenland, using transient inversion techniques to infer unknown basal conditions.



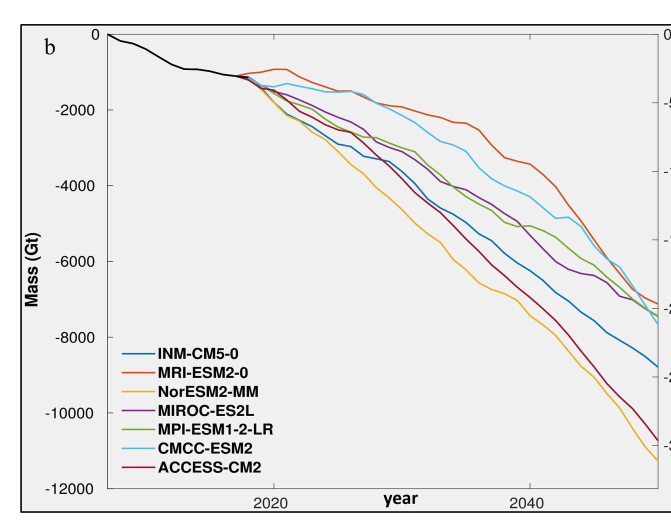
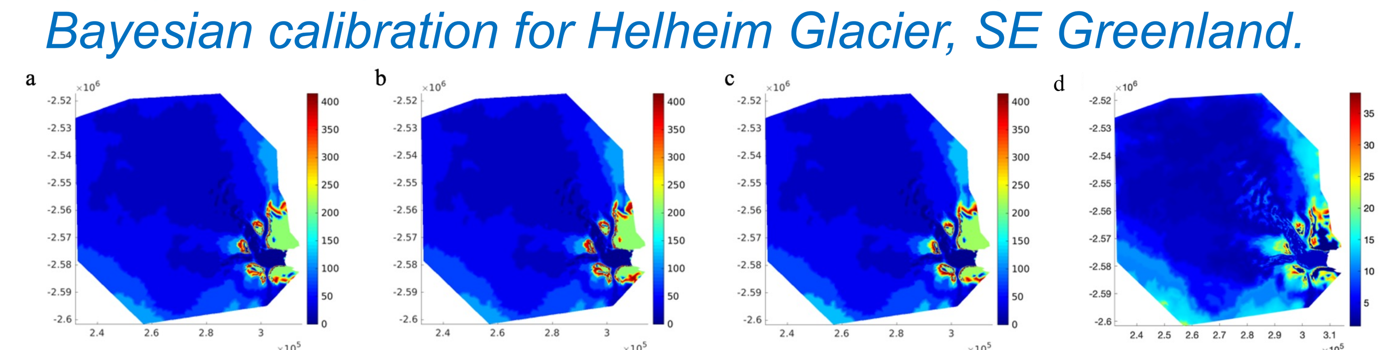


Figure 2: a) GEMB + ISSM projected thickness change by 2050, forced by CMIP6 high-emission (ssp85) INM-CM5-0 model output. b) Greenland mass change and sea-level equivalent (SLE) projections, forced by an ensemble of ssp85 model output.

Figure 3: (a-c) Candidates for the basal friction coefficient [$(m/s)^{-1/2}$] using "DTUQ4" and d) uncertainty estimated from Bayesian calibration for Helheim Glacier, SE Greenland.



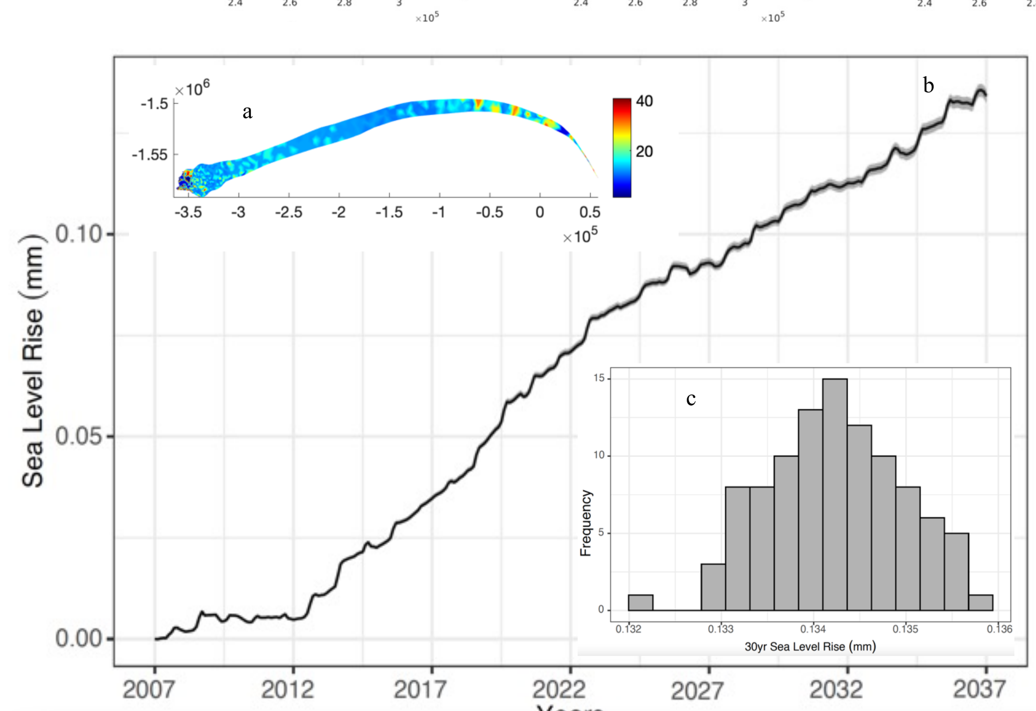


Figure 4: a) As Fig. 3d but for Kjer Glacier. b) The propagation of a) through a 30-year simulation of global mean sea-level contribution. c) The resulting probability density function of sea-level contribution by year 2037.

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Select Publications:

Y. Choi, H. Seroussi, A. S. Gardner, & N.-J. Schlegel (2022) "Uncovering basal friction in northwest Greenland using an ice flow model and observations of the past decade", Journal of Geophysical Research - Earth Surface, 127, e2022JF006710. https://doi.org/10.1029/2022JF006710.

H.H. Bajgiran, P.B. Franch, H. Owhadi, M. Samir, C. Scovel, M. Shirdel, M. Stanley, and P. Tavallali (2022). "Uncertainty Quantification of the 4th kind; optimal posterior accuracy-uncertainty tradeoff with the minimum enclosing ball", Journal of Computational Physics, in press, https://arxiv.org/abs/2108.10517.

A. Gardner, N.-J. Schlegel, and E. Larour (2022) "Glacier Energy and Mass Balance (GEMB v1.0): A model of firn processes for cryosphere research", Geosci. Model Dev., in revision.

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