An Inversion Algorithm to Investigate the State of Friction at the Base of the Greenland Ice Sheet

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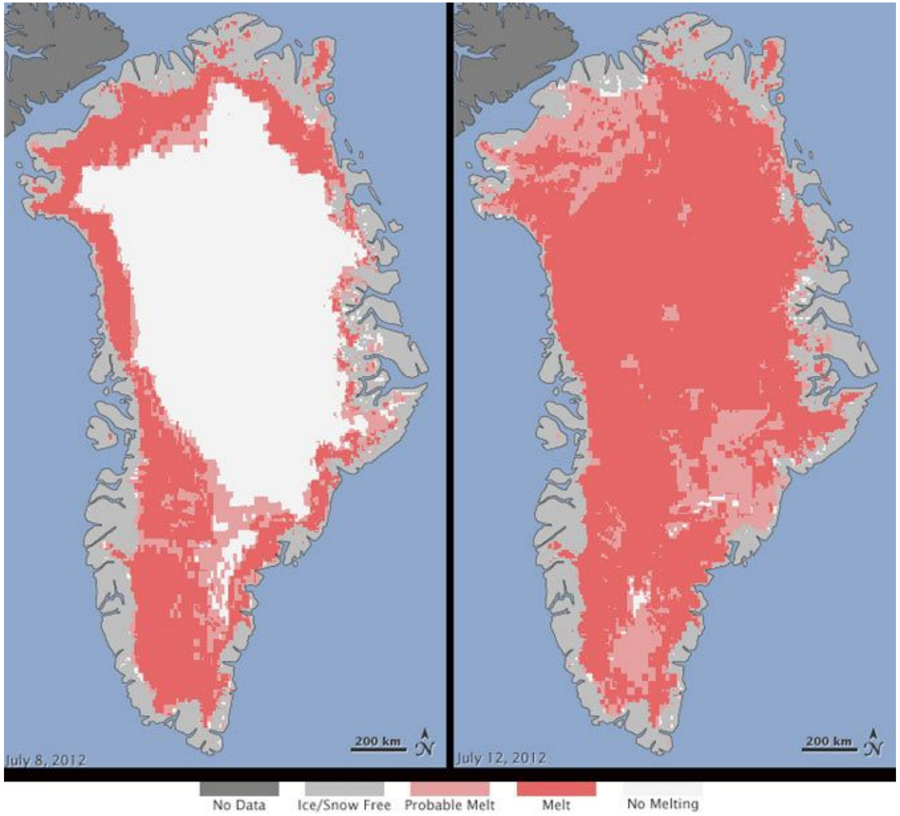
Introduction

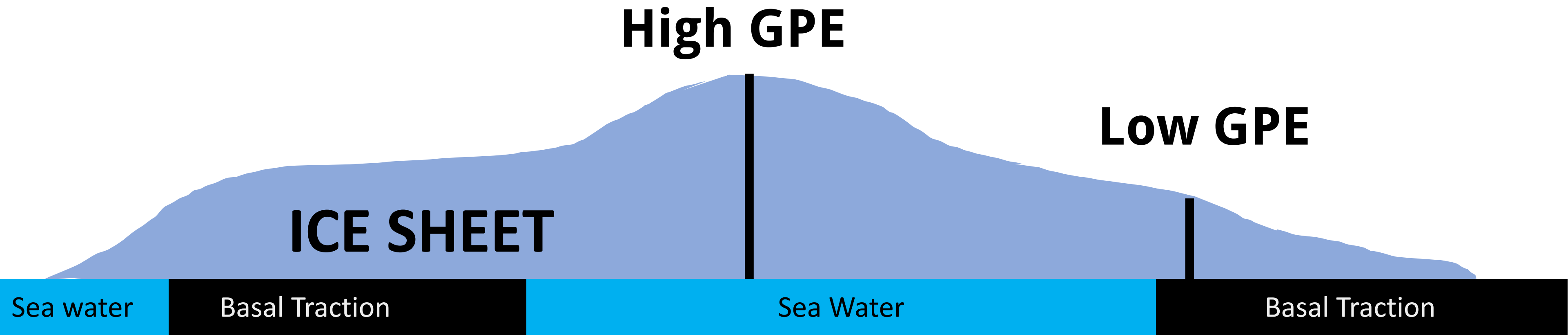
- The Greenland Ice Sheet (GrIs) has been melting at an alarming rate
  - Losing 200 Gt ice /year
  - Largest contributor to rising global sea levels
- To combat rising sea levels, it is imperative to understand these ice flow dynamics



Source: NASA

Previous Works

- Prior work analyzed GrIs flow leveraging Ice Thickness and associated gravitational potential energy (GPE) data
- GPE calculations were unable to account for basal tractions
- Our work developing an inversion algorithm to quantify basal tractions bridges this gap

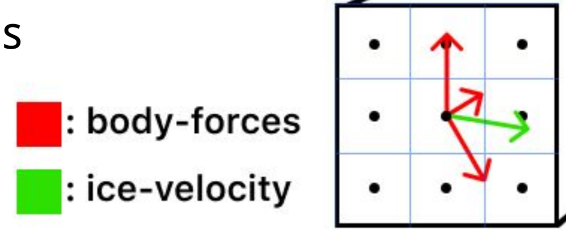


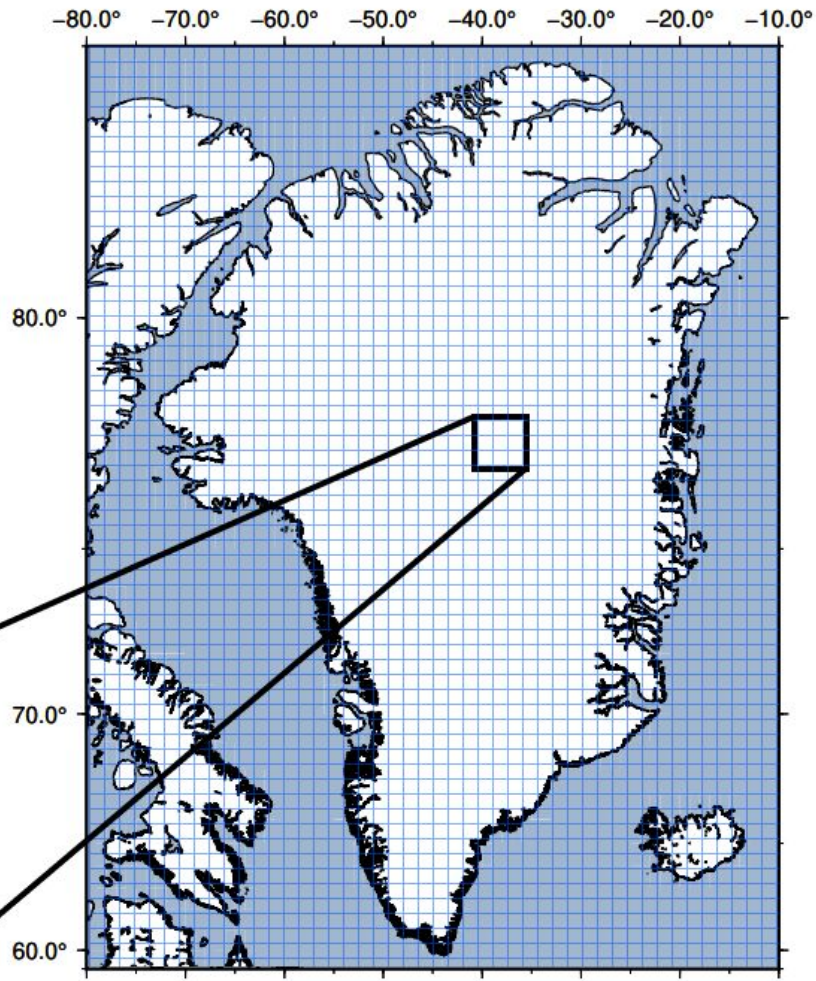
Methods

- Our dataset is sourced from ETOPO1 topographical ice sheet and Sentinel-1 InSAR velocity measurements
- $\vec{d} = \bar{\bar{G}}m = v_{InSAR} - v_{GPE}$
  - $\vec{d}$: velocity field derived from velocity of InSAR – velocity of GPE
  - $\bar{\bar{G}}$: Basis functions representing viscous thin-sheet responses caused by body-forces on the ice sheet
  - m: linear inversion model
- Goal to find best linear combination ($\bar{\bar{G}}m$) that predicts $\vec{d}$

Methods - $\overline{\overline{G}}$

- Partitioned Greenland into 1000 2° x 2° grid cells
- 3 Basis Functions for each grid cell:
  - E_xx – Horizontal East and West effective body-forces
  - E_yy – Horizontal North and South effective body-forces
  - E_xy – Shear effective body-forces



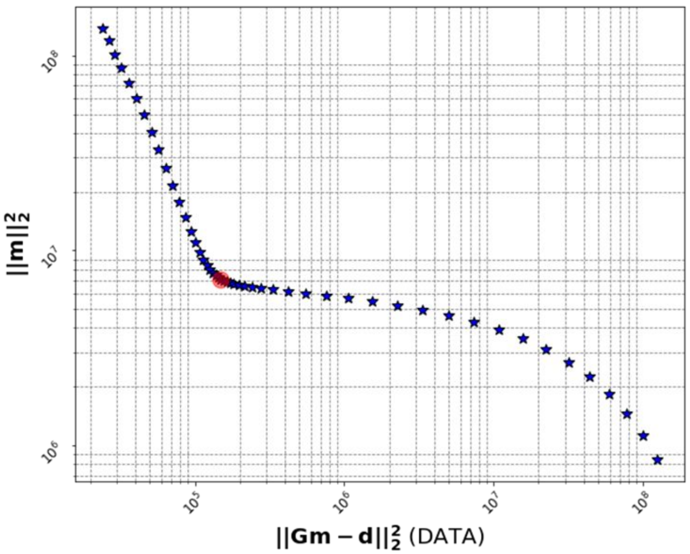


Methods - $\boldsymbol{m}$

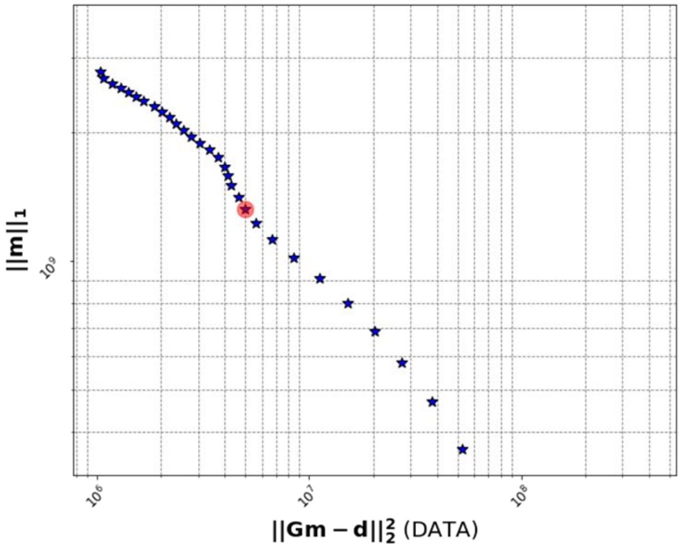
- Employed Linear Regression Algorithm from sklearn library
- Applied the Least Squares Method (LSM) with the Ridge (Tikhonov) and LASSO regularization to optimize our model
- LASSO Loss: $\left|\left|\bar{\bar{G}}m - \vec{d}\right|\right|_2 + \alpha^2 \|m\|_1$
- Ridge Loss: $\left|\left|\bar{\bar{G}}m - \vec{d}\right|\right|_2 + \alpha^2 \|m\|_2^2$
- Used the trade-off (L-curve) criterion to determine an “optimal” smoothing parameter

Results

Ridge Trade Off Curve



LASSO Trade Off Curve

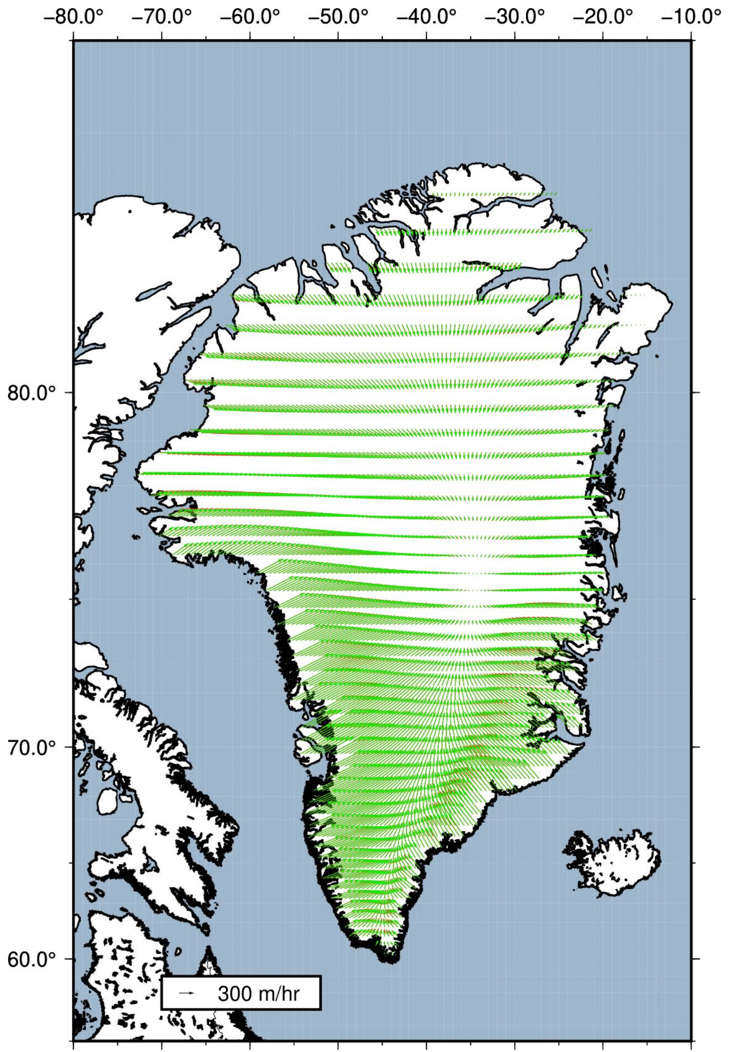


Optimal Smoothing Parameters + Performance Metrics

	Best α	R^2	RMSE	MAE
Ridge	**0.1520**	**0.9734**	**6.3651**	**4.3038**
LASSO	0.0324	0.9552	27.679	24.323

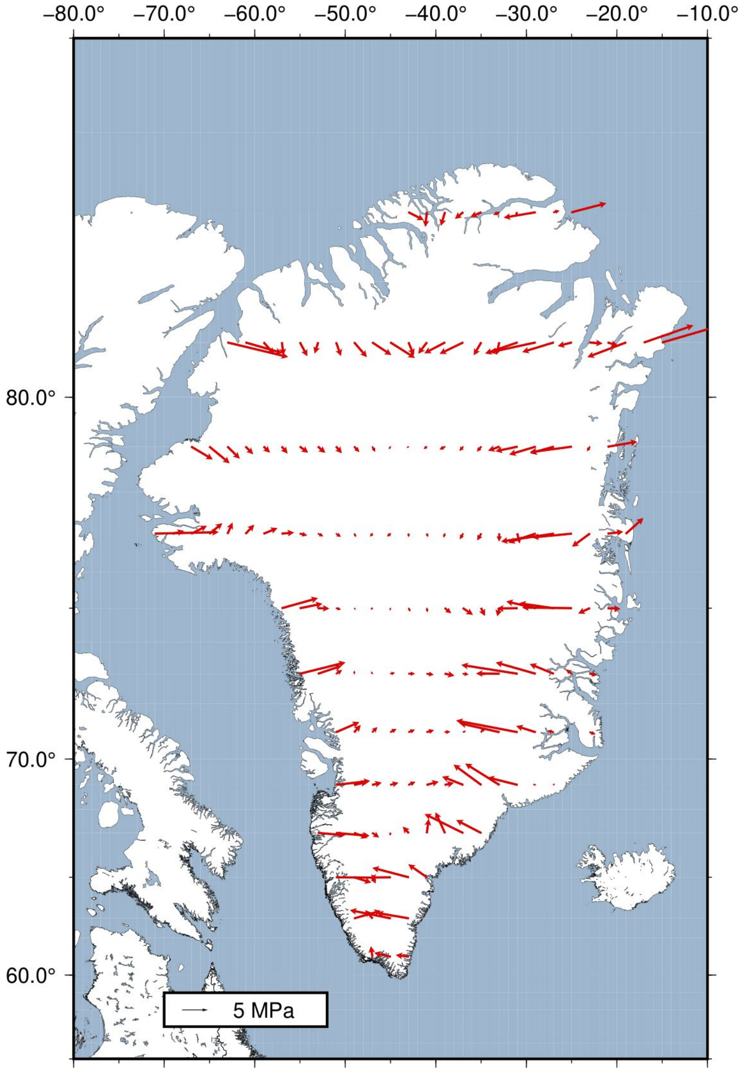
Results

- Model predictions for GrIs horizontal velocity fields:
- InSAR velocities (red arrows) and model's predicted velocities (green arrows)
- Model achieves near identical fit
- Discrepancies most prevalent near edges as a result of grid cell resolution



Results

- Model Basal Traction Predictions:
- Uncovers magnitudes and distributions of basal tractions across GrIs
- Basal Tractions lie around GrIs coastline
- Work enables scientists to relate changes in basal tractions to change in ice velocities and flux



Conclusions

- Successfully predicted horizontal velocity field and associated basal tractions
- Enhances knowledge of ice flow, uncovering relationships between basal traction, velocity fields, and ice flux
- Demonstrates the promise of applying ML to gain a deeper understanding of ice sheets, giving us valuable insight towards rising sea levels needed in the fight against climate change.
- Future Works will explore use of deep learning and applications to Antarctic