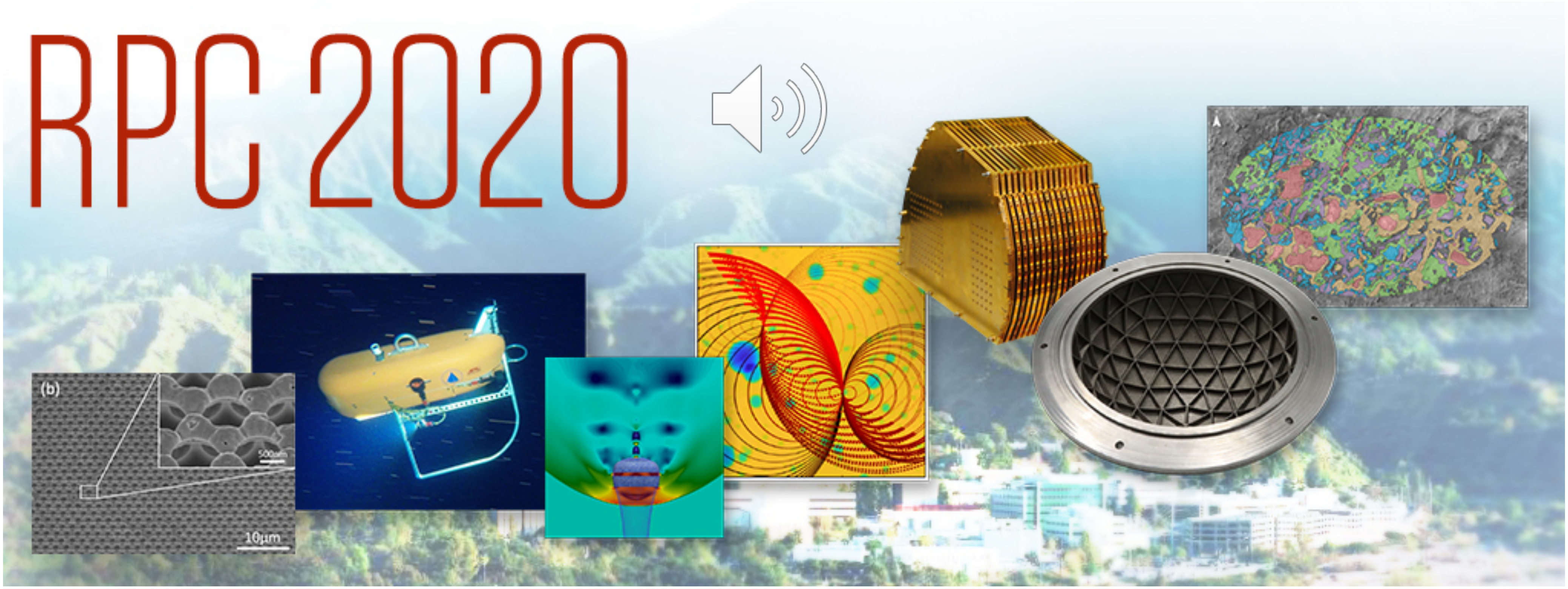

Virtual Research Presentation Conference

Greenland contribution to Sea Level by 2050: the role of meltwater in shaping the future ice sheet evolution

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Tutorial Introduction

Abstract

This project is part of the Earth 2050 initiative, a JPL/campus effort to improve our understanding of fundamental climate science questions. It will specifically address the stability of the Greenland Ice Sheet and its contribution to sea level rise in a warming climate over the next 30 years. It will consolidate the link between the JPL expertise on ice observations and JPL's ice and ocean modeling group. It will also initiate a new collaboration between JPL and campus in uncertainty quantification, and develop new uncertainty quantification methodologies specifically for science applications.

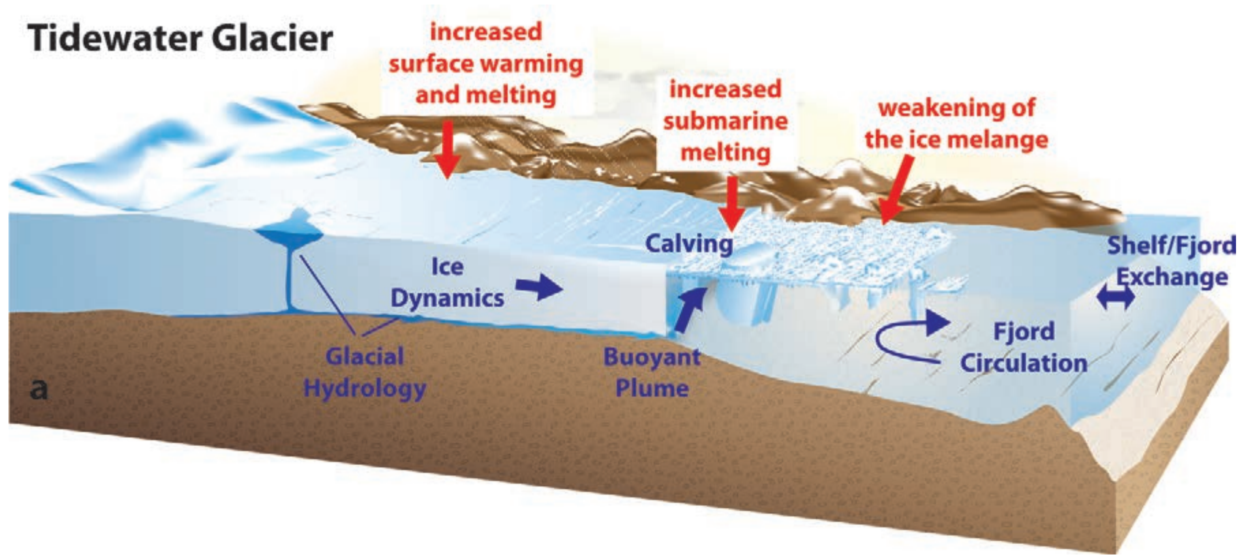

Figure 1: Schematic of a Greenland tidewater glacier including key mechanisms [1]

Problem Description

a) Projections of ice sheets evolution and their contribution to sea level focused mostly on 100-500 year timescale, but decadal timescale is critical for policy makers and infrastructure adaptation

Satellite observations now available for the past 30 years and can be used to better initialize and validate ice flow models for decadal timescale simulations

b) ISSM (Ice Sheet System Model) state-of-the-art ice flow model and simulations performed include surface processes, ice front retreat and assimilation of remote-sensing observations

Uncertainty Quantification based on new game theoretical approach

c) Development of new framework for ice flow projections, with enhanced use of observations, improved representation of ice dynamics, surface processes, and robust estimation of uncertainties

Observations

a) Methodology

- Compilation of extensive dataset of glacier state from 1985 to present
- 182 largest glaciers around Greenland included
- Algorithm for performance of model results

b) Results

- Timeseries of glacier velocity, ice flux at glaciers' terminus and evolution of ice front position (see example on Figure 2)
- Identification of glaciers capturing ice front retreat and/or acceleration

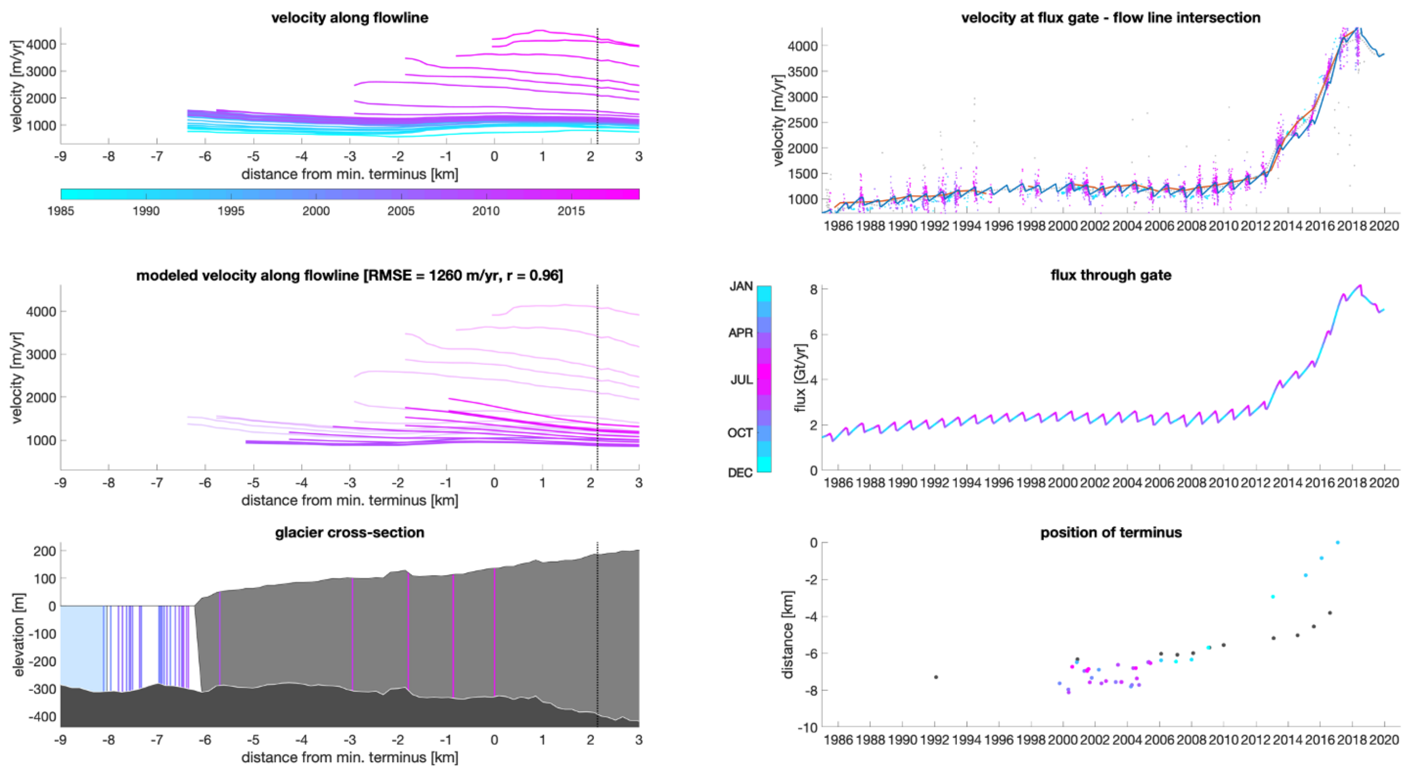

Figure 2: Observation of Kjer Glacier for the 1985-2018 period: a) surface velocity, b) comparison of observed and modeled velocity (see also Figure 4), c) geometry of the centerline and ice front positions, d) velocity at the glacier terminus, e) ice flux at the terminus and f) ice front.

Surface processes

a) Methodology

- GEMB (Glacier Energy and Mass Balance) model embedded in ISSM
- New capabilities for 3 hourly forcing from reanalysis, integration of albedo data, long spinups and calibration of firn densification [A]

b) Results

- Improved agreement with firn compaction observations and better snowpack properties
- Simulations of firn evolution over entire Greenland ice sheet for 2012-2015 period
- Simulations will be extended to the 1979-2020 period

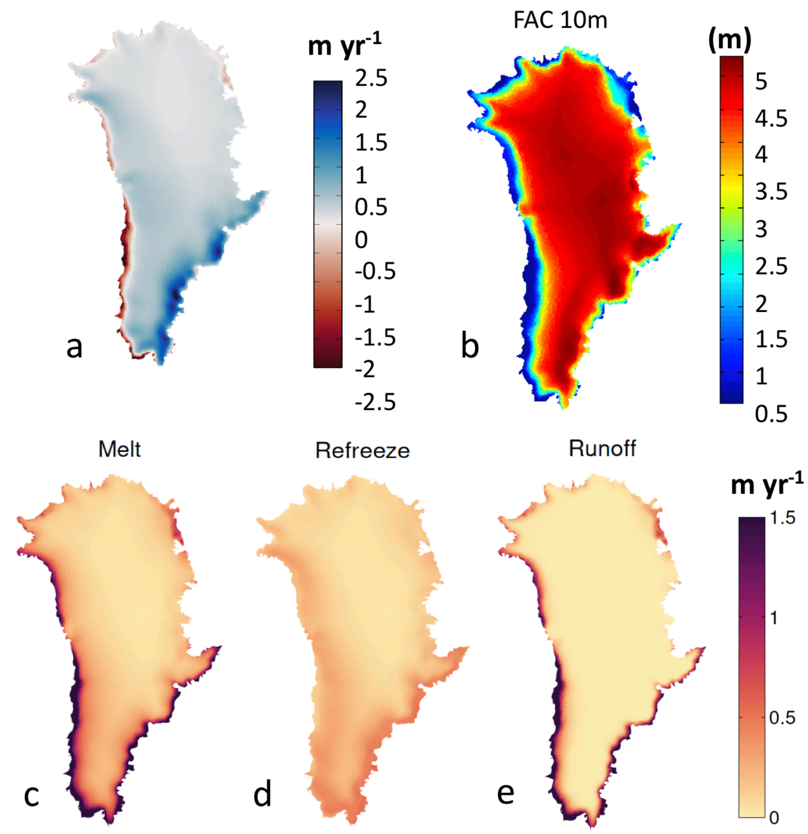

Figure 3: GEMB forced with ERA5 over the 2012-2015 period. Results are modeled estimates of mean 2012-2015 for a) surface mass balance (SMB), SMB melt components c) melt, d) refreeze and e) runoff, and b) firn air content (FAC) integrated to a depth of 10 m.

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Ice dynamics

a) Methodology

- Simulations of Greenland for 2007-2018 period
- Regional simulations with forced ice front retreat and several sliding laws and parameters

b) Results

- Overall agreement of mass loss in Greenland but discrepancies in ice acceleration, even when ice front evolution consistent with observations
- Ice acceleration consistent with observations for Budd sliding law (see Figure 4) and higher exponents than commonly used (more plastic bed)
- Results will be extended to other regions and longer periods

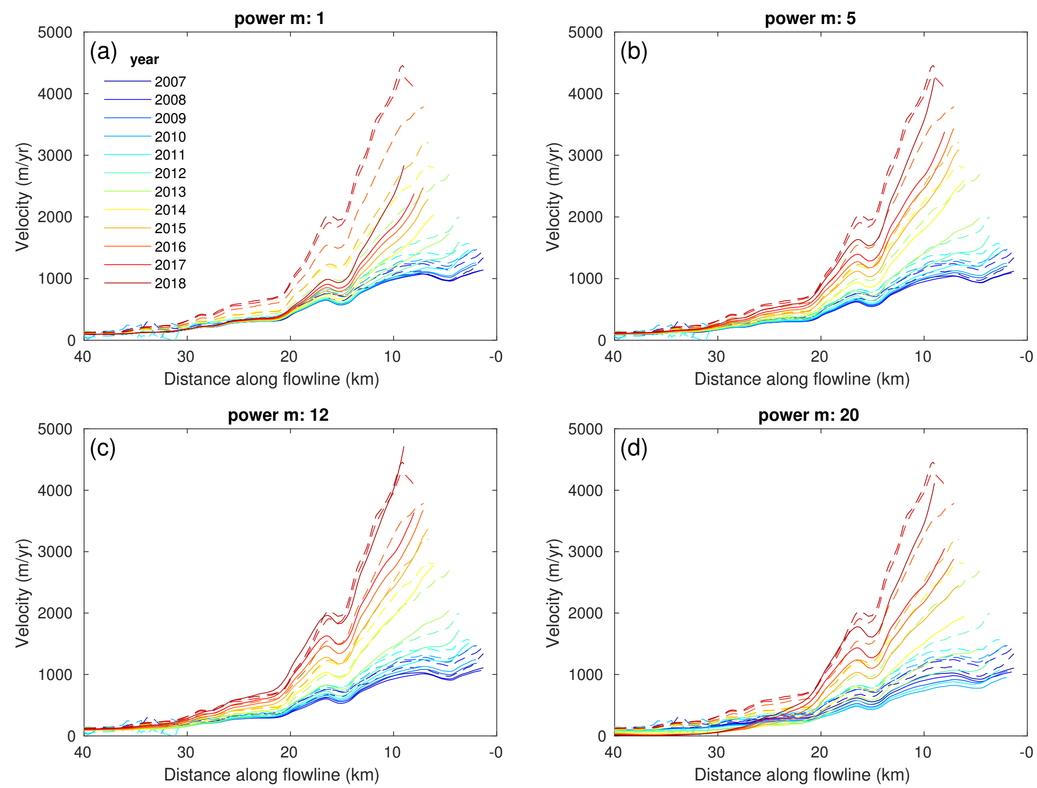

Figure 4: Observed velocity (dashed lines) for Kjer glacier in Central West Greenland, from 2007 to 2018 and modeled velocity (solid lines) using a Budd friction law (tau_b=C*N*v^(1/m)). Exponents used in the Budd friction law are a) m=1, b) m=5, c) m=12 and d) m=20.

Uncertainty Quantification

a) Methodology

- Development of algorithm for game theoretical approach: incorporation of computation and complexity in a generalization of Wald's decision framework built on Von Neumann's theory
- Development of algorithm to combine machine learning with game theoretical approach

b) Results

- Application to estimate uncertainties of basal friction coefficient (see Figure 5)

Next step is to develop and implement regret free approach that combines worst case, Bayesian and game theoretical approaches

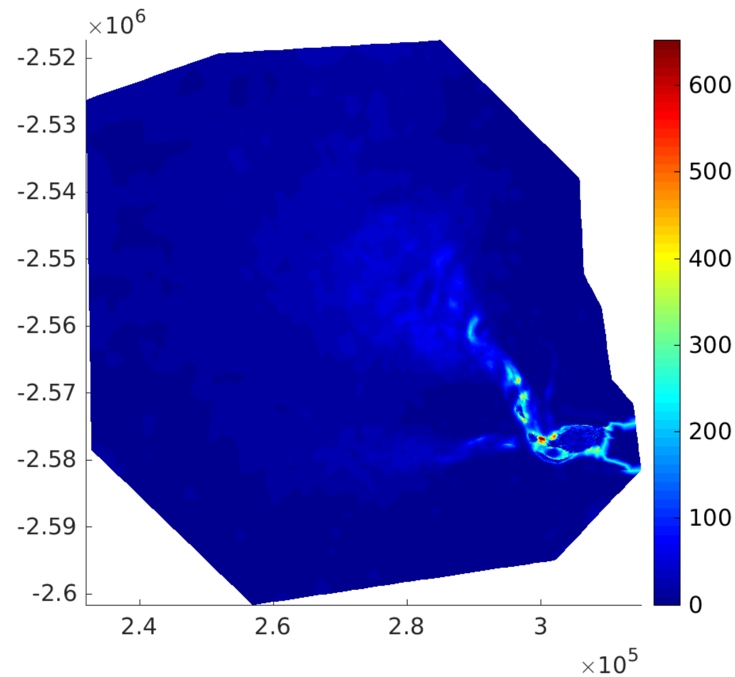

Figure 5: Uncertainties in basal friction for Helheim glacier in Southeast Greenland. Uncertainty in basal friction coefficient (in %) estimated using assimilation of surface velocities and adversarial game theoretical approach.

Publications and References

[A] A. Gardner, N.-J. Schlegel, E. Larour et al., 2020, “Glacier Energy and Mass Balance (GEMB) v1: A model of firn processes for cryosphere research”, Geosci. Model Dev., in prep.

[1] F. Straneo, P. Heimbach, O. Sergienko, G. Hamilton, G. Catania, S. Griffies, R. Hallberg, et al. “Challenges to Understanding the Dynamic Response of Greenland’s Marine Terminating Glaciers to Oceanic and Atmospheric Forcing.” Bull. Amer. Meteor., 94 (8), 1131-1144, doi:10.1175/BAMS-D-12-00100.1