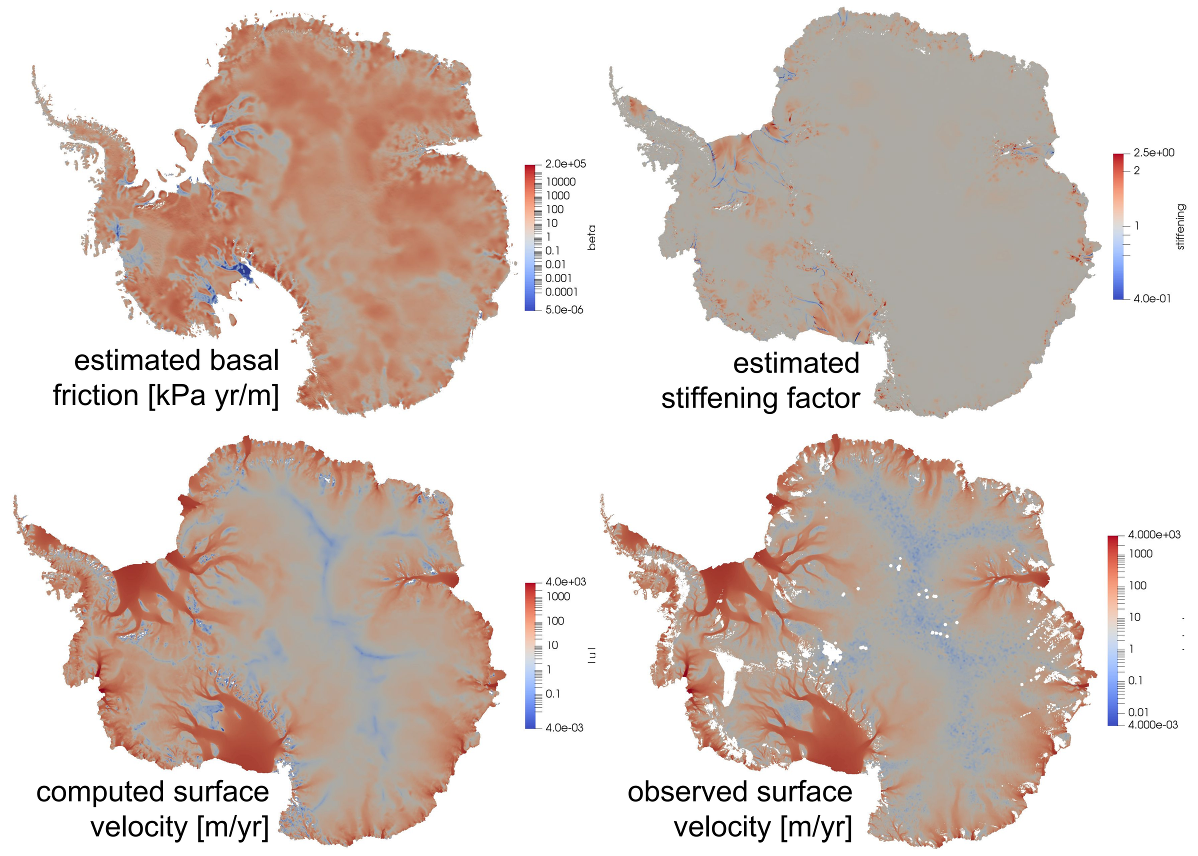
Probabilistic Sea-Level Projections from Ice Sheet and Earth System Models
2: Ice Sheet Model Optimization, V&V, and UQ

Optimization

Goal:
- Before assessing ice sheet sensitivity to climate, the ice sheet model must be initialized to match current ice sheet observations and trends. Optimization algorithms are used for the data assimilation step.

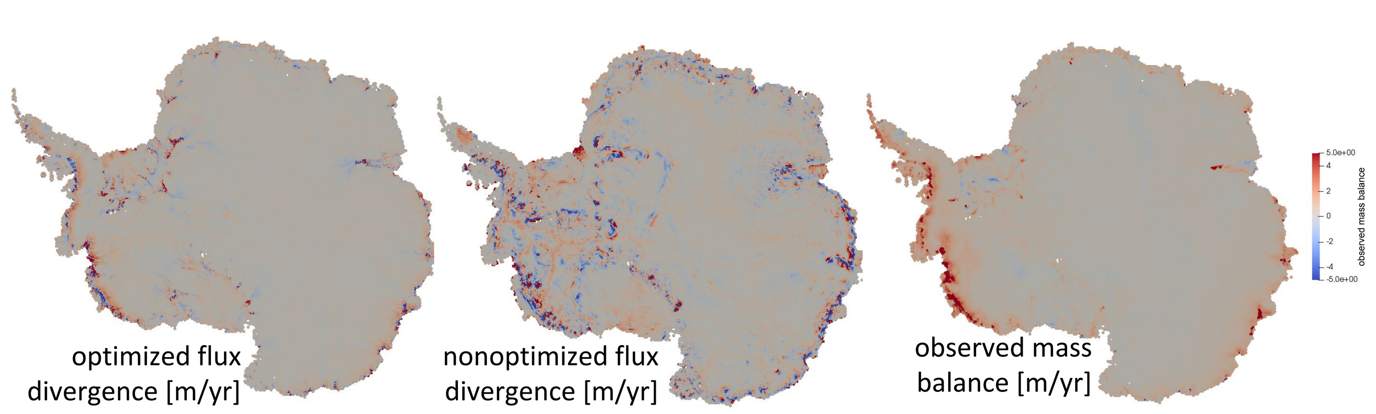
Tasks:
- Provide deterministic inversion (MAP point) and sensitivities to be used in inference problem and science (e.g. MIPs) experiments.
- Simultaneously invert for multiple parameters to improve agreement with observations and reduce unphysical transients.

Progress:
- Initialized Antarctic ice sheet inverting simultaneously for different fields (basal friction, stiffening factor, ice thickness) for a total of 2.6 million parameters.
- Improved computation of sensitivities using the Trilinos Tpetra stack. This will enable performance portability (w/ **FASTMath**).



Challenge:
- Inversion of ice thickness (constrained to be self consistent w/ the computational model and climate forcings) proved to be very challenging especially when inverting simultaneously for other field.

In order to avoid unphysical transients the flux divergence of the computational model should match the observed mass balance. Optimization minimizes the mismatch allowing to avoid/reduce use of costly "spin-up".

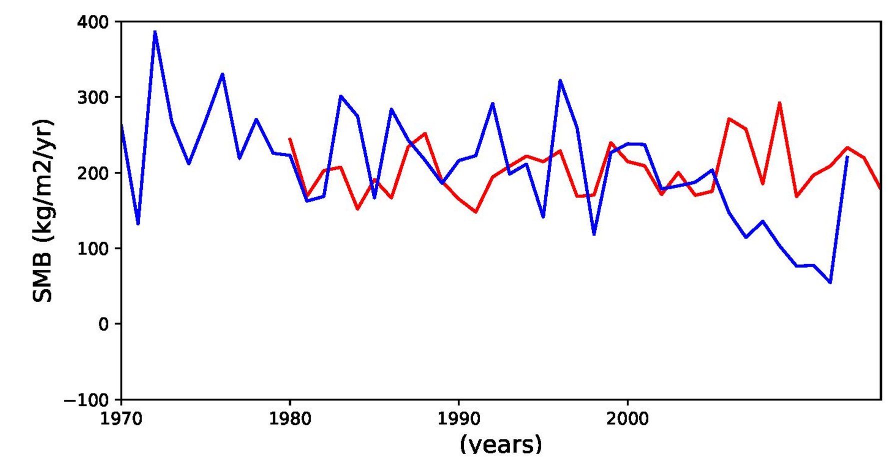


Verification & Validation

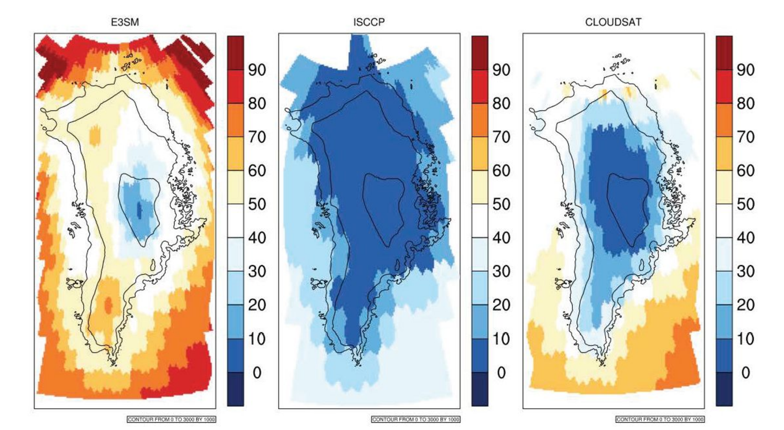
Goal:
- We will automate the process of verifying and validating our ice sheet models and the relevant climate model forcing.

Tasks:
- Enable full surface mass balance validation in E3SM over Antarctica and Greenland
- Enable physical validation of ice dynamics in MALI and BISICLES
- Enable performance V&V of BISICLES and MALI

Progress:
- LIVVkit 2.1 includes a pseudo-SMB analysis of E3SM v1 using available output fields with extended analysis of atm and lnd coupling related fields
- Development of glc-mec (land) to allow a E3SM v1 restart to output of all required SMB fields for analysis
- Developed (preliminary) high-resolution Antarctic model input dataset and comparison masks



Times series of the E3SM v1 (blue) of a surface mass balance like variable for 1970-2005, compared to the (orange) RACMO2.3 (orange).



Climatological annual average of low clouds (%) over the GrIS for E3SM (left), ISCCP (middle), and CLOUDSAT (right). The downscaled E3SM values are used for all elevation contours. Refer to Evans at al. (2018) for details.

Challenge:
- Data wrangling; discovering, acquiring, processing, cleaning, and analyzing data from many disparate data and modeling centers is time and effort intensive, often involving creation of new grids, masks, etc.

Synergistic activities to interact with observational and ice sheet modeling communities for V&V activities:
1. initMIP: intercomparison of model initialization techniques; refer to Geotzler et al. (2018)
2. Participants in GriOOS, the Greenland Ice Sheet-Ocean Observing System (GrIOOS)
3. forming connections to RAPIDS and participation in the ADIOS-ECP review committee to connect to advanced data processing
4. Leading a model verification focused mini-symposium at SIAM MPE Sept 2018.

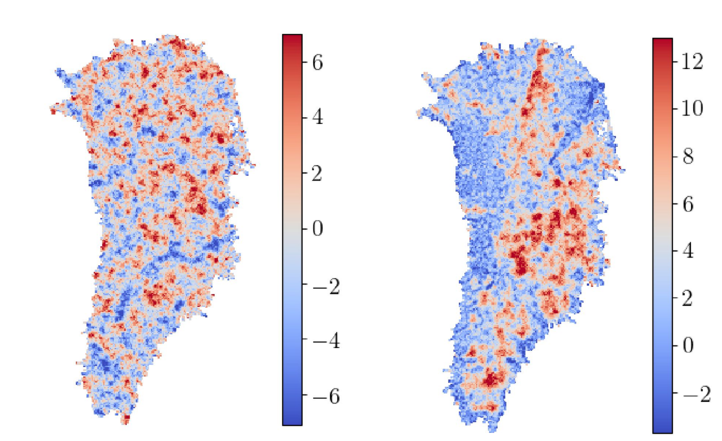
K. J. Evans et al. (2018). LIVVkit 2.1: Automated and extensible ice sheet model validation, Geo. Model Dev, under review.

Uncertainty Quantification

Goal:
- We are working towards providing uncertainty estimates on sea level rise predictions using UQ methodologies that scale to our large problem sizes.

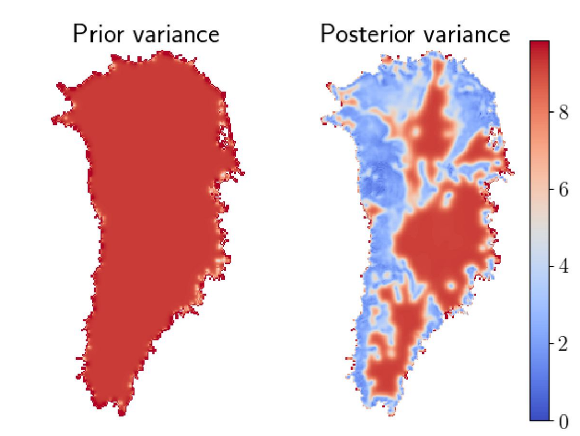
Tasks:
- Infer basal friction uncertainties.
- Propagate these uncertainties forward in time assuming steady climate forcing to estimate uncertainties in 21st century sea-level change projections.

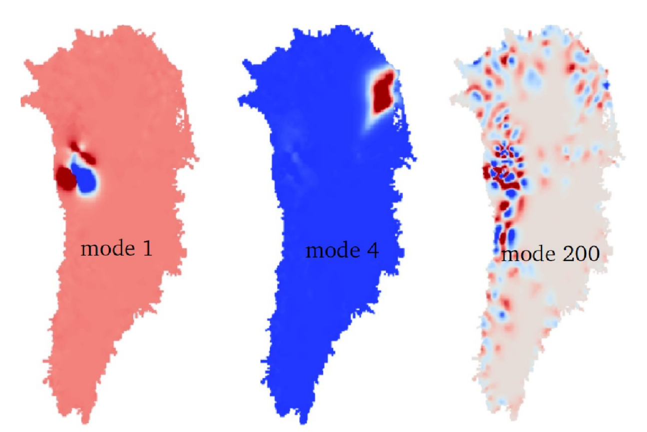
Progress:
- Performed Bayesian Inference of 26 thousands random variables, for 8km resolution realistic Greenland ice sheet problem, using a low rank Gaussian approximation of the posterior distribution (Isaac, Petra, Stadler, Ghattas) to reduce computational complexity.



Bayesian inference

(left) sample from the prior and corresponding sample from posterior distribution. (right) prior and posterior variance.

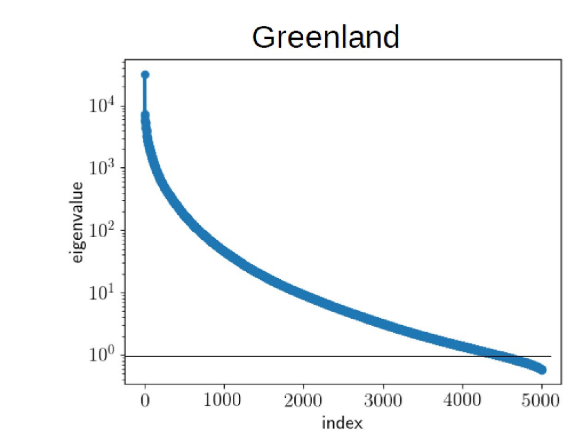




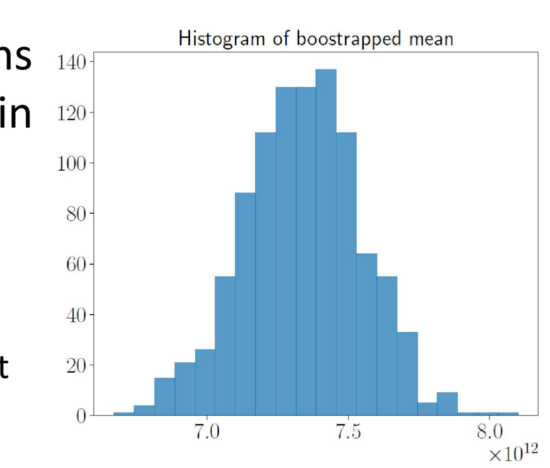
Low-rank approximation

(left) eigenvectors form the prior preconditioned Hessian. (right) eigenvalues of the prior-precoditioned Hessian

O(10^3) significant eigenvalues



Challenge:
- The assumption that the prior and posterior distributions are Log-Gaussian leads to a non-physical positive bias in the mean predicted sea-level change.



Right: Histogram of net sea level change after 100 years, resampled (bootstrapped) from 100 forward model simulations of the Greenland ice sheet (8 km uniform resolution) under steady-state surface mass balance.

E3SM Energy Exascale Earth System Model

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https://doe-prospect.github.io/

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