Title: Large-scale deterministic inversion and Bayesian calibration in land-ice modeling

MS Topic: Bayesian Statistical Inversion in Engineering Mechanics

User: Irina Tezaur (ikalash) | ikalash@sandia.gov

Authors **Irina Tezaur (Presenting),** John Jakeman, Mauro Perego, Stephen Price,

Abstract Text:

Mass loss from the polar ice sheets is expected to have a significant contribution to future sea-level changes. Predictions of ice sheet evolution are fraught with uncertainty, which comes from a number of sources, including poorly known model parameters, incomplete knowledge of ice-sheet initial and boundary conditions, uncertain future climate forcing, and sparsity/imprecision of observational data used to constrain ice sheet models.

This talk will describe some of our work in quantifying uncertainties in ice sheet model inputs, in particular initial and boundary conditions, using formal methods of optimal parameter estimation and uncertainty quantification (UQ), in conjunction with computational tools that orchestrate these methods. After describing our project for land-ice modeling, known as PISCEES (Predicting Ice Sheet Climate Science Evolution at Extreme Scales) and our FELIX (Finite Elements for Land Ice eXperiments) land-ice simulation tool, we will detail the "end-to-end" workflow we have developed to provide probability distribution functions (PDFs) on ice sheet model outputs of interest (e.g., ice sheet mass loss over time). This workflow consists of three stages: (1) deterministic inversion, (2) Bayesian calibration, and (3) forward propagation of uncertainty. To remain within the scope of this minisymposium, attention is focused on the first two stages. Specifically, we will discuss approaches for estimating the basal friction coefficient, an important high-dimensional parameter used to define the initial and boundary conditions in ice sheet models, under the presence of uncertainty.

First, we will describe our approach for inverting for the basal friction by solving a large-scale partial differential equation (PDE)-constrained optimization problem that minimizes the model mismatch with observations of surface ice properties (e.g., surface velocity, surface mass balance). We then turn our attention to solving this inverse problem in a Bayesian setting, that is, determining the PDF of the basal friction given uncertainties, e.g., measurement error or noise, in the observed quantities. Our deterministic optimization is consistent with its Bayesian analog: it is used to find the MAP point of the posterior distribution. To address the challenge of the curse of dimensionality in the Bayesian inverse problem, we assume our posterior PDF is a Gaussian whose covariance is the square root of an elliptic partial differential equation, namely a low rank Laplace approximation, where the rank is the number of directions (linear combinations of the parameters) that informed directions of the posterior. We present results of the proposed inversion/calibration approaches on several Greenland ice sheet problems with varying resolutions.