Preliminary Quantification of Uncertainty in Parameters of the Glaciers and Small Ice Caps Melt Model

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ABSTRACT

Glaciers and Small Ice Caps (GSICs) contribute to sea-level rise. Previous studies have used semi-empirical models to derive projections of GSIC melt.. Wigley and Raper(2005) modified a glacier melt model Intergovernmental Panel on Climate Change Third Assessment Report which projects future sea level-rise. Here we present preliminary results to quantify the sensitivity of this model to its parameters and to quantify the uncertainty surrounding the parameter estimates. This approach has the potential to yield a better understanding of what drives sea-level rise due to GSIC melt, to improve projections, and to inform the design of climate risk management strategies.

INTRODUCTION

- Semi-empirical glacier models have been produced which project future sea level from the melting of GSICs.
- Model projections of the contribution of sea level rise from GSIC ranges from 0.08 to 0.39 m sea level equivalent in 2100. [1]
- We recreate a semi-empirical model from Wigley and Raper which is an extended model of IPPC TAR that uses the melt parameters: β_0, V_0, n, and the intial contribution of GSICs to project future sea level rise. [2]
- Many times model input/output relationships are poorly understood which leads to a need for sensitivity analysis.
- Model parameters are sources of uncertainty which can limit how confident scientists or decision makers are with the response of the model.
- This study uses statistical methods to answer the following questions:
  - How sensitive is the model to its parameters?
  - What values should these parameters be set to?
  - What is the range of uncertainty about the parameters that make up the glacier melt model?
  - How different are the projections with the range of uncertainties?

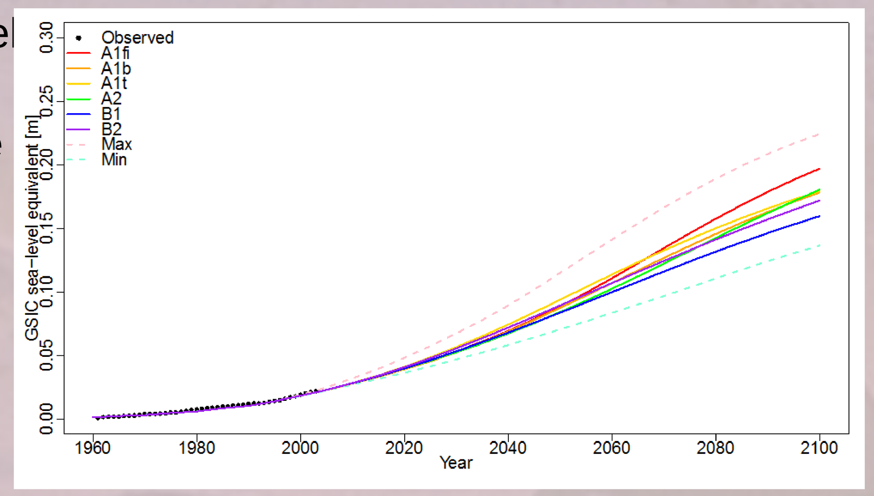

Figure 1: Comparison of Best Guess hindcasts and projections for each IPCC future emission scenario. The max scenario has a temperature change of 5.80ºC and the min has a temperature change of 1.37ºC.

GSIC MELT ALGORITHM

- The surface mass balance algorithm is based on the work of Gregory and Oerlemans [1998] and Van der Wal and Wild [2001] in which the total melt in sea level equivalent is calculated assuming the GSIC volume will stay constant and corrected so that the mass balance sensitivity will decrease as the volume of GSIC decreases when melting occurs. [3,4]
- The original algorithm works to 2100; however, Wigley and Raper modified the formula to extend it to 2400 by using global mass balance sensitivity as a function of the GSIC area directly:

$$Dg_s/dt = \beta_0(0.15 + T(t))(1 - g_s/V_0)^n$$

Symbol	Meaning	Units	Bounds	Best Estimate	90% C.I.
β_0	mass balance sensitivity	cm/yr/C	0-1	0.142	0.121-0.168
V_0	initial volume of all GSIC in 1961	cm	30-50	30	31.0-48.9
n	exponent related to the size of GSIC	dimensionless	0.65-1.5	1.5	0.696-1.45
Initial Value (InV)	GSIC sea-level rise contribution in 1961	cm	unconstrained	0.132	-0.015-0.204

METHODS

- R programming language
- Estimate the best fit by minimizing the root mean squared error using Differential Evolution [5]
- Use a bootstrap resampling method to estimate the uncertainty surrounding the parameter estimates. We assumed independent and identically distributed errors. [6]
- Time series and temperatures dataset from National Oceanic and Atmospheric Administration [7]
- GSIC Data from National Snow & Ice Data Center [8]
- A2 future emission scenario which has a cumulative greenhouse gas emission of ~1350-1850 GtC from 1990-2100 and a 3.79C temperature change in 2100 [9]

RESULTS

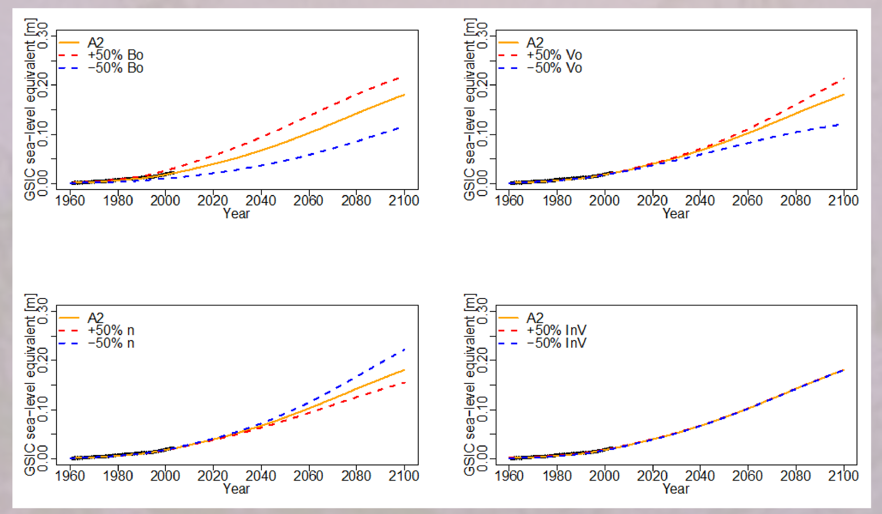

Figure 2: Best Guess hindcast and projections and sensitivity study with respect to the four analyzed parameters.

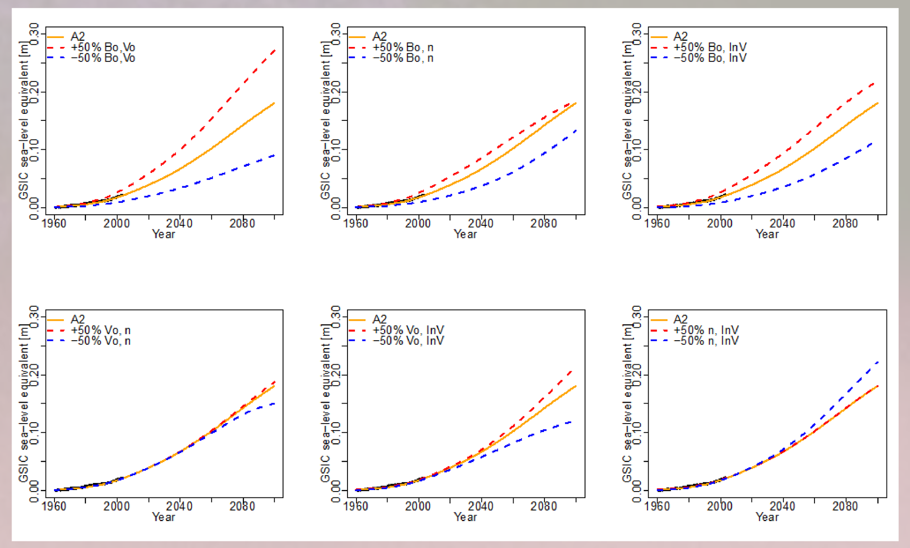

Figure 3: Best Guess hindcast and projections and sensitivity study with respect to varying two of the four analyzed parameters.

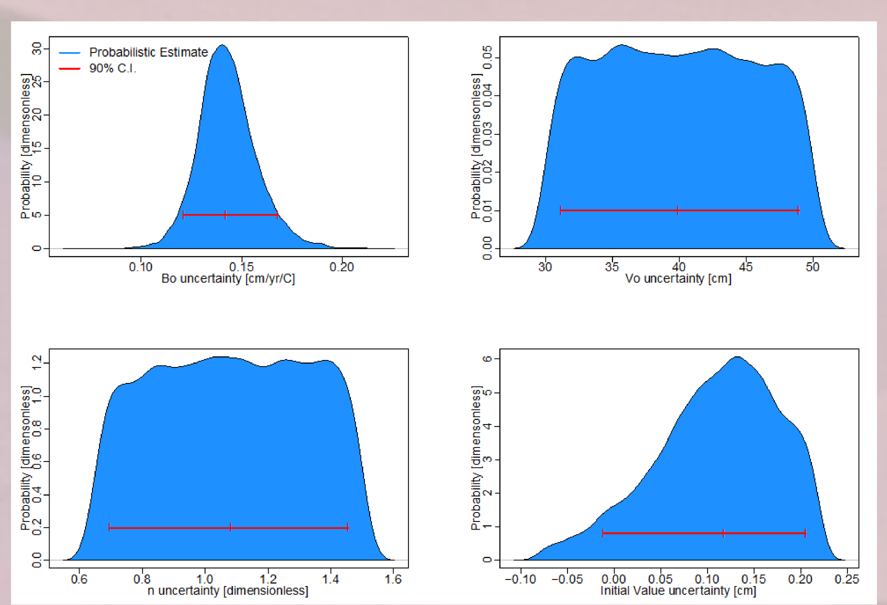

Figure 4: Probabilistic estimate of each parameter by resampling the Differential Evolution best fit parameters.

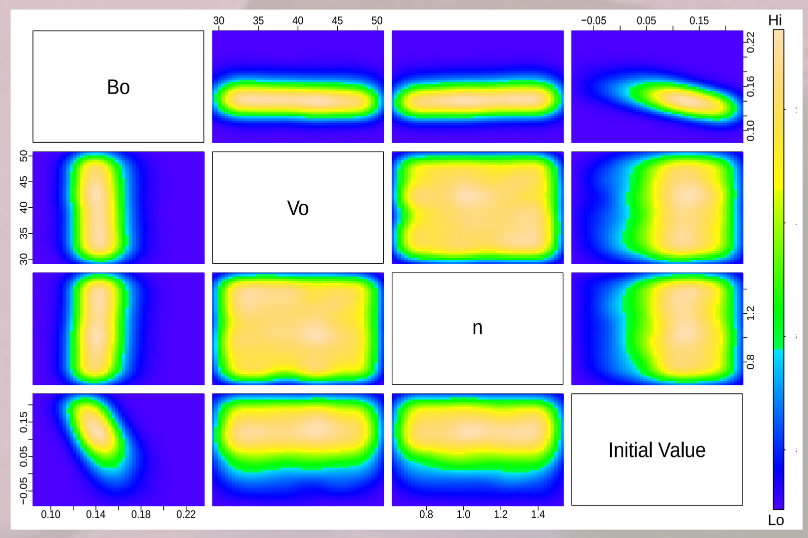

Figure 5: Density image that shows the correlation between the parameter estimates derived from the bootstrap.

RESULTS

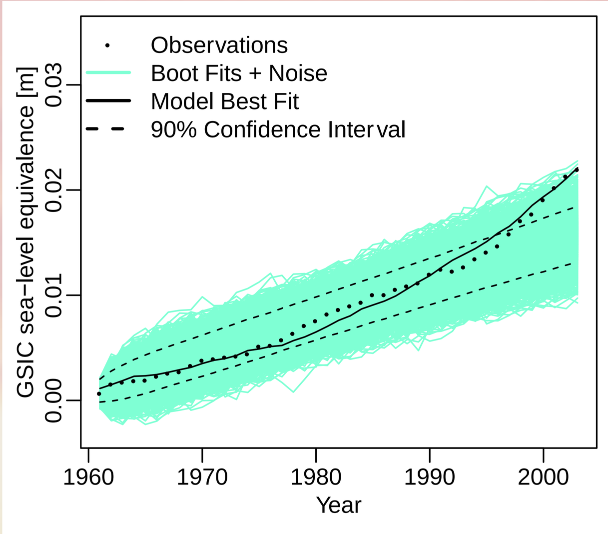

Figure 6: Preliminary comparison of the hindcasts to show the range of uncertainty and Best Guess hindcast. The boot fits + noise deviate from the model best fit and indicates a problem.

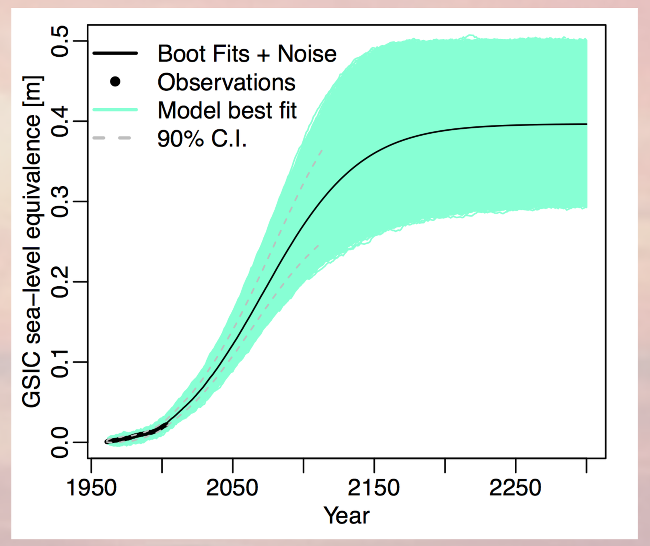

Figure 7: Preliminary RCP8.5 emission scenario hindcast and projection out to 2300. By ~2150 GSICs reach their maximum contribution to sea-level rise. (RCP8.5 scenario is an updated version of the A2 scenario.[10])

DISCUSSION/CONCLUSIONS

- The GSIC melt model is mainly sensitive to changes in B_0 and V_0 which cause an increase in sea level rise as they increase and n which causes an increase in sea level rise an it decreases.
- Bootstrapping the estimation allows us to assess not just the best estimate of the parameter values, but also the associate d uncertainties. These results are preliminary and still need to be carefully tested. For example, we see evidence that the bootstrap method, as implemented, has a problem as the hindcast is biased and the uncertainties seem too wide. This is a work in progress. We hypothesize that this is a bug in our code.

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